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Elucidating the determinants between the environment and individuals' behaviors amidst the COVID-19 pandemic and the post-COVID era

Edited by
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Elucidating the determinants between the environment and individuals' behaviors amidst the COVID-19 pandemic and the post-COVID era

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Table of contents

06 Mental health and cognitive function among medical students after the COVID-19 pandemic in China
Junzhe Cheng, Mei Liao, Ziping He, Rui Xiong, Yumeng Ju, Jin Liu, Bangshan Liu, Bei Wu and Yan Zhang

13 Impact of forestry on environment and human health: an evidence-based investigation
Abdullah Addas

28 Potential impacts of Russo-Ukraine conflict and its psychological consequences among Ukrainian adults: the post-COVID-19 era
Ahsan Riaz Khan and Ali Altalbe

37 Health perception and restorative experience in the therapeutic landscape of urban wetland parks during the COVID-19 pandemic
Jiang Li, Yating Chang, Xiaoxi Cai, Shaobo Liu, You Peng, Tao Feng, Jialing Qi, Yifeng Ji, Yiting Xia and Wenbo Lai

53 Exploring the potential impact of group identity on post-traumatic growth in the aftermath of Corona outbreak: function of social–emotional competence as a mediator
Jinfu Ma, Ahsan Riaz Khan, Hai-Jun Zhang, Zhang Jun, Mohamed R. Abonazel, Muhammad Salman Ahmad, Elsayed M. Tageldin and Ali Rashash R. Alzahran

62 Psychological factors associated with vaccination hesitancy: an observational study of patients hospitalized for COVID-19 in a later phase of the pandemic in Italy
Carla Comacchio, Maddalena Cesco, Rosita Martinelli, Marco Garzitto, Rita Bianchi, Nicola Innocente, Emanuela Sozio, Carlo Tascini, Matteo Balestrieri and Marco Colizzi

70 Subjective assessment of occupational stress and mental health of nurses during the Covid-19 pandemic period
Krystyna Kowalczuk, Katarzyna Tomaszewska, Joanna Chilińska, Elżbieta Krajewska-Kułak, Marek Sobolewski and Justyna M. Hermanowicz

80 The positive effects of positive coping on mental health in college students during the COVID-19 campus lockdown
Meiqi Li and Lijun Chen

86 Is the COVID-19 epidemic affecting the body mass of Chinese teenagers? – A longitudinal follow-up study
Guoyang Qin, Hui Li, Yong Qin and Bin Liu

93 3D indoor modeling and game theory based navigation for pre and post COVID-19 situation
Jaiteg Singh, Noopur Tyagi, Saravjeet Singh, Babar Shah, Farman Ali, Ahmad Ali AlZubi and Abdulrhman Alkhanifer

107 Sociodemographic factors affecting not receiving COVID-19 vaccine in Japan among people who originally intended to vaccinate: a prospective cohort study
Akiko Matsuyama, Takahiro Mori, Akira Ogami, Kosuke Mafune, Seiichiro Tateishi, Mami Kuwamura, Keiji Muramatsu, Yoshihisa Fujino, Koji Mori and CORoNaWork project

114 The relation between barrier-free environment perception and campus commuting satisfaction
Jiang Li, Chuyu Zhang, Xiaoxi Cai, You Peng, Shaobo Liu, Wenbo Lai, Yating Chang, Yudan Liu and Liang Yu

128 Public mental health through social media in the post COVID-19 era
Deepika Sharma, Jaiteg Singh, Babar Shah, Farman Ali, Ahmad Ali AlZubi and Mallak Ahmad AlZubi

140 Stress, resilience, and moral distress among health care providers in oncology during the COVID-19 pandemic
Waleed Alrjoub, Ghadeer Alarjeh, Khawlah Ammar, Abedalrahman Shamieh, Richard Harding, Christopher Booth, Richard Sullivan, Majeda Al-ruzzieh, Asem Mansour and Omar Shamieh

152 Prevalence and associated risk factors for mental health problems among young adults in Fiji Island during COVID-19: a cross-sectional study
Mohammad G. M. Khan, Muhammad Mainuddin Patwary, Kabir A. Mamum, Aneesh A. Chand, Kaamil Edward, Kushal A. Prasad, Matthew H. E. M. Browning, Chaandvi Prasad and Faysal Kabir Shuvo

164 Telepresence robots as facilitators of physical exercise during COVID-19: a feasibility and acceptance study
Abdullah Addas

177 Exploring the relationship of cognitive function with and without COVID-19 recovered schizophrenic patients
Anam Mehmood, Ali Madi Almajwal, Abdullah Addas, Falak Zeb, Iftikhar Alam and Bismillah Sehar

188 Risk communication and community engagement in the context of COVID-19 response in Bangladesh: a qualitative study
Mohammed Kamruzzaman, Aminur Rahman, Daniel D. Reidpath and Sadika Akhter

198 Prevalence, attitudes and concerns toward telepsychiatry and mobile health self-management tools among patients with mental disorders during and after the COVID-19 pandemic: a nationwide survey in Poland from 2020 to 2023
Monika Dominiak, Adam Gędek, Anna Z. Antosik and Paweł Mierzejewski

210 Prevalence and correlates of suicidal ideation in the general public during the fifth wave of COVID-19 pandemic in Hong Kong
Heidi Ka Ying Lo, Joe Kwun Nam Chan, Corine Sau Man Wong, Gabbie Hou Sem Wong, Janet Hiu Ching Lei, Yuen Kiu So, Vivian Shi Cheng Fung, Ryan Sai Ting Chu, Rachel Ling, Albert Kar Kin Chung, Krystal Chi Kei Lee, Calvin Pak Wing Cheng, Wai Chi Chan and Wing Chung Chang

221 Hospital pharmacists' mental health during home isolation in the post-pandemic era of COVID-19: influencing factors, coping strategies, and the mediating effect of resilience
Zhao Yin, XiangYu Wang, Xiaojing Lu and Hang Fu

232 Explaining differences in self-focused and other-involved public health preventive behaviors between the US and China: the role of self- construal and health locus of control
Wenjing Pan, Wang Liao, Bo Feng and Siyue Li

243 Retrospective study on the emotional status of healthcare workers in a COVID-19 field hospital in Oman
Roopa Koshy McCall, Hamed Al-Sinawi, Nutaila Al-Kharusi, Sulaiman Al Rawahi, Rola Al Balushi, Nabil Al-Lawati, Manfredi Rizzo, Khalid Al-Rasadi and Abdullah Al Maniri

254 Environmental and geographical factors influencing the spread of SARS-CoV-2 over 2years: a fine-scale spatiotemporal analysis
David De Ridder, Anaïs Ladoy, Yangji Choi, Damien Jacot, Séverine Vuilleumier, Idris Guessous, Stéphane Joost and Gilbert Greub

271 Assessing the impact of the COVID-19 pandemic on the mental health of female entertainment workers in Cambodia: a group model building approach
Calida S. Chua, John P. Ansah, Sovanvorleak Tep, Sreymom Oy, Mengieng Ung and Siyan Yi

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Mental health and cognitive function among medical students after the COVID-19 pandemic in China

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Background: Chinese people experienced a nationwide coronavirus disease 2019 (COVID-19) pandemic after the adjustment of epidemic response policies from December 2022 to January 2023. This study aims to explore the prevalence of mental and cognitive symptoms and their associated factors among medical students after the COVID-19 pandemic.

Methods: A cross-sectional study was conducted between February 27th and March 8th, 2023. The symptoms of anxiety, depression, insomnia, post-traumatic stress disorder (PTSD), and cognitive function among medical students were examined using the Generalized Anxiety Disorder-7 (GAD-7), the Patient Health Questionnaire-9 (PHQ-9), the Athens Insomnia Scale (AIS), the Impact of Event Scale-6 (IES-6), and the Perceived Deficits Questionnaire-Depression-5 (PDQ-D-5). Data on demographic information was also collected. Statistical analyses were conducted to describe the prevalence and explore the associated factors of mental and cognitive symptoms.

Results: Among 947 participants, the proportion of students experiencing anxiety, depression, insomnia, and PTSD symptoms was 37.8, 39.3, 28.3, and 29.5%, respectively. The self-reported COVID-19 infection rate was 72.2%. Higher grades, childhood, and current rural residence were identified as potential risk factors for mental and cognitive symptoms. Gender, age, average monthly household income, and COVID-19 diagnosis were not associated with mental and cognitive symptoms among medical students.

Conclusion: Our findings revealed a high prevalence of mental and cognitive symptoms among Chinese medical students after the COVID-19 pandemic. Special attention should be paid to the mental health of higher-grade students and those residing in rural areas.

KEYWORDS

medical students, post-COVID-19 period, mental health, cognitive function, risk factors

1. Introduction

With the alterations of the Chinese epidemic prevention policy, China experienced a nationwide wave of the coronavirus disease 2019 (COVID-19) pandemic from December 2022 to January 2023. The Chinese Center for Disease Control and Prevention (CDC) reported a 6.94 million peak in the number of infected people (1). According to reports, the general public's physical and mental health has been adversely affected by the COVID-19 epidemic (2, 3). To embark on targeted therapies after the COVID-19 pandemic, it is imperative to emphasize people's mental health and identify the susceptible population. Compared to other social populations, college students exhibited a higher vulnerability to the COVID-19 outbreak, encountering uncertainty and unexpected disruptions to their academic semesters (4). The COVID-19 pandemic and subsequent quarantine measures gave rise to various outcomes for college students (5). They found it challenging academically to transition from traditional face-to-face learning to online learning (6, 7). Long-term isolation at home and minimal social interaction may contribute to mental disorders, including depression and anxiety (8).

Medical students were considered a high-risk group for suffering from mental disorders (9). The mental health of medical students had already started to deteriorate prior to the COVID-19 pandemic (10–12). Some of them even actively participated in efforts to provide COVID-19 aid during the pandemic (11, 13). Additionally, lockdown measures including digital learning, home quarantine, and social distancing were unprecedented experiences for them. A cross-sectional survey conducted on medical students in China showed that the outbreak of COVID-19 aggravated medical students' negative emotional outcomes (14). During the long-term pandemic, medical students tended to suffer from several cognitive symptoms and mental disorders, such as anxiety, depression, insomnia, post-traumatic stress disorder (PTSD), and cognitive dysfunction (15–17). The impaired mental health and cognitive function may negatively impact the future professional identity and capacity to care for patients. Examining the extent of physical and psychological well-being in the post-epidemic era is crucial for ensuring the future quality of healthcare services (18).

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Previous studies primarily investigated the physical and mental well-being of college students during the early stage of the pandemic from 2020 to 2022 (19, 20). Although extensive research has been conducted on the initial phases of the epidemic, inadequate effort has been emphasized for medical students in the post-COVID-19 period. However, most of the students who were infected during the first wave of the COVID-19 pandemic in China were psychologically prepared for the subsequent infection, given their prior experience. As a result, they may perceive themselves well-informed about the pandemic during this period, which might reduce their anxiety and fear (21, 22). Moreover, residence (urban or rural) and family income stability are also associated with psychological well-being (23). In response, we conducted a survey on Chinese medical students to investigate the prevalence and severity of mental and cognitive symptoms and their associated factors, and to provide validated empirical data on mental health and cognitive function after the COVID-19 pandemic. Our study was expected to enrich the evidence of mental health and cognitive function among medical students in the post-COVID-19 period and provide clues for identifying a targeted population for psychological intervention.

2. Methods

2.1. Participants and study design

A cross-sectional survey was conducted offline using nonprobability sampling among medical students. It started on February 27th, 2023, and ended on March 8th, 2023, after China experienced the first round of the COVID-19 pandemic nationwide. The survey was administered offline using paper questionnaires at Central South University, Changsha, Hunan, China. A total of 1,049 medical students participated in the survey. Every student who followed the survey gave informed consent about the research protocol. Participants who met the following criteria were included: (1) medical students, (2) students studying at Central South University, and (3) volunteered for the survey. The exclusion criteria included missing or inadequate information and/or any major physical or mental illness. Ultimately, 947 medical students were included in the study.

2.2. Ethical considerations

This study had been approved by the Ethics Committee of the Second Xiangya Hospital of Central South University (approval number: 047).

2.3. Measurements

2.3.1. Demographic information

Participants provided demographic information on their age, gender, grade, average monthly household income, childhood residence, current residence, history of physical illness, psychiatric history, and whether they had been diagnosed with COVID-19 infection.

2.3.2. Anxiety symptoms

The seven-item General Anxiety Disorder-7 (GAD-7) was used to record anxiety symptoms (24). Participants rated the frequency of

experiencing seven symptoms during the previous 2 weeks as: (0) not at all, (1) on several days, (2) on more than half of the days, and (3) nearly every day. Scores range from 0 to 21, with higher scores indicating more anxiety symptoms. The total score S of GAD-7 is categorized as follows: $S \leq 4$ = minimal symptoms; $5 \leq S \leq 9$ = mild symptoms; $10 \leq S \leq 13$ = moderate symptoms; $14 \leq S \leq 18$ = moderately severe symptoms; $S \geq 19$ = severe symptoms. With a Cronbach's alpha of 0.879, the GAD-7 in the current sample shows a strong level of internal consistency.

2.3.3. Depressive symptoms

Depressive symptoms were assessed using the nine-item Patient Health Questionnaire (PHQ-9) (25, 26). A Likert scale (0 = "Not at all" to 3 = "Nearly every day") was used to assess the frequency of experiencing nine symptoms during the previous 2 weeks. Scores range from 0 to 27, with higher scores indicating more depressive symptoms. The total score S of PHQ-9 is categorized as follows: $S \leq 4$ = minimal symptoms; $5 \leq S \leq 9$ = mild symptoms; $10 \leq S \leq 14$ = moderate symptoms; $15 \leq S \leq 19$ = moderately severe symptoms; $S \geq 20$ = severe symptoms. The PHQ-9 in the current sample has shown an internal consistency of 0.908 (Cronbach's alpha).

2.3.4. Insomnia

The eight-item Athens Insomnia Scale (AIS) was used to record the severity of insomnia for all subjects (27). A Likert scale including five items related to sleep difficulties and three related to daytime functional impairment (0 = "Not at all" to 3 = "Extremely") was used to assess the severity during the past month. The total score ranges from 0 to 24 points. Previous studies have confirmed that a score of 6 is a reasonable cutoff for insomnia (28). On this basis, an AIS score < 4 was defined as normal, a $4 \leq$ score < 6 was defined as suspected insomnia, and a score ≥ 6 was defined as insomnia. The AIS in the current sample has internal consistency (Cronbach's alpha, 0.805).

2.3.5. PTSD symptoms

The level of PTSD is usually measured by the Impact of Event Scale-6 (IES-6) for research in epidemiological studies or clinical practice. IES-6 is validated and shortened based on the Impact of Events Scale-Revised (IES-R) (29). Participants were asked to report their PTSD symptoms in the past 7 days on six items from 0 (not at all) to 4 (extremely). Scores range from 0 to 24, with higher scores indicating more PTSD symptoms. It can associate the COVID-19 pandemic with PTSD symptoms through its three subscales (intrusion, avoidance, and hyperarousal). We used the mean score S of IES-6 to measure the level of PTSD: $S < 1.09$ = normal; $1.09 \leq S < 1.5$ = showing PTSD symptoms; $S \geq 1.5$ = may be diagnosed with probable PTSD (30). The IES-6 in our study sample showed an internal consistency of 0.862 (Cronbach's alpha).

2.3.6. Cognitive dysfunctions

The five-item Perceived Deficits Questionnaire-Depression (PDQ-D-5) was used to record the severity of self-reported cognitive symptoms over the previous 7 days (31). The frequency of experiencing these symptoms is rated using a scale ranging from 0 to 4 (0 = "not at all" to 3 = "nearly every day"). The total score ranges from 0 to 20, with higher scores indicative of more severe cognitive symptoms. With a Cronbach's alpha of 0.852, the PDQ-D-5 in the current sample exhibits a favorable score for internal consistency.

2.4. Statistical analysis

Data were analyzed using SPSS Version 25.0 (IBM SPSS, Armonk NY, USA). Descriptive statistical analyses were conduct to exhibit the sample's demographic profile and level of mental health and cognitive function. Reliability tests were used to check the internal consistency of IES-6, GAD-7, PHQ-9, AIS, and PDQ-D-5 in the current sample. Based on the data type and data distribution, independent t-tests, person correlation analysis and spearman correlation analysis were respectively adopted to examine the relationships between participants' demographics and mental health, sleep quality, and cognitive function. A two-tailed $p<0.05$ was considered statistically significant.

3. Results

3.1. Demographic characteristics

The general demographic characteristics of these 947 medical students are shown in Table 1. The final sample of participants for the present study consisted of 947 medical students, with a median age of 18.88 (SD: 0.23) years and the majority of participants between the ages of 15 and 24. Four hundred and fifty-nine (48.5%) male and five hundred and twelve (51.5%) female participants responded to the survey. The sample of medical students consists of 521 freshmen (55.0%) and 426 sophomores (45.0%). Most participants had an

TABLE 1 Demographic characteristics of the responders (n = 947).

Variables		
Continuous variables		*Means ± SD*
Age (years)		18.88 ± 0.923
Categorical variables		*No. (%)*
Gender	Male	459 (48.5)
	Female	512 (51.5)
Grade	Freshman	521 (55.0)
	Sophomore	426 (45.0)
Average monthly household income	<1,000	38 (4.0)
	1,000–5,000	438 (46.3)
	5,000–10,000	292 (30.8)
	10,000–50,000	167 (17.6)
	>50,000	12 (1.3)
Childhood residence	Rural	310 (32.7)
	Urban	617 (65.2)
	Prefer to no answer	20 (2.1)
Current residence	Rural	145 (15.3)
	Urban	778 (82.2)
	Prefer to no answer	24 (2.5)
Diagnosed with Covid-19?	Yes	684 (72.2)
	No	170 (18.0)
	Not sure	93 (9.8)

SD: Stand deviation.

average monthly household income of <10,000 yuan (81.1%). Most participants had the urban census register in childhood (65.2%), and the ratio has increased to 82.2% at present. Most participants reported a history of a positive diagnosis of COVID-19 (72.2%).

3.2. The prevalence of anxiety, depression, insomnia, and PTSD symptoms

Overall, the proportion of participants reporting mild, moderate, moderately severe, and severe anxiety symptoms was 28.0, 6.1, 2.7, and 1.0%, respectively. The proportion of participants reporting mild, moderate, moderately severe, and severe depressive symptoms was 30.2, 6.3, 1.9, and 0.8%, respectively. The proportions of participants reporting suspected insomnia and insomnia were 31.2 and 28.3%, respectively. Whereas, the proportions of participants reporting PTSD symptoms and probable PTSD were 13.2 and 16.3%, respectively (Figure 1).

3.3. Factors associated with mental and cognitive symptoms

Table 2 displays the factors that may be associated with mental and cognitive symptoms. There were no significant gender differences in either mental health or cognitive function. It was found that compared to freshmen, sophomores had higher levels of anxiety symptoms ($p = 0.03$), depressive symptoms ($p < 0.01$), insomnia ($p < 0.01$), and PTSD symptoms ($p < 0.01$). Moreover, there was no significant difference in cognitive symptoms between different grades. The rural students showed significantly higher cognitive symptoms both in their childhood residence ($p < 0.01$) and current residence ($p = 0.03$) than the urban students. However, there was no significant difference in mental health and cognitive function whether the participant was diagnosed with COVID-19 or not.

In the correlation analysis of age with mental problems and cognitive symptoms, the grade was considered as a covariate. Childhood and current residence were taken as covariates in the correlation analysis of average monthly household income with mental problems and cognitive symptoms. Table 3 displays the results of the bivariate partial correlation analysis of age, average monthly household income, anxiety, depression, insomnia, PTSD, and cognitive symptoms. There were statistically significant positive correlations between anxiety, depression, insomnia, PTSD, and cognitive symptoms. None of the mental or cognitive symptoms were significantly correlated with age or the average monthly household income.

4. Discussion

To the best of our knowledge, this is the first study that has examined the mental health and cognitive function of medical students after the first nationwide COVID-19 pandemic in China. Particularly, few studies investigated the cognitive function of medical students during or after the COVID-19 pandemic. The proportions of medical students who experienced symptoms of anxiety, depression, insomnia, or PTSD were 37.8, 39.3, 28.3, and 29.5%, respectively, which were significantly higher than general college students post COVID-19 pandemic (32–34). A cross-sectional study of medical students in Greece during the COVID-19 pandemic reported a higher prevalence of anxiety (67.6%), depression (43.7%), and insomnia (65.9%) than our study (35). It is possible that in our study, with sufficient knowledge about the coronavirus infection and long-term adaptation to the pandemic and quarantine policies, the prevalence of mental and symptoms in medical students faded away to a lower level.

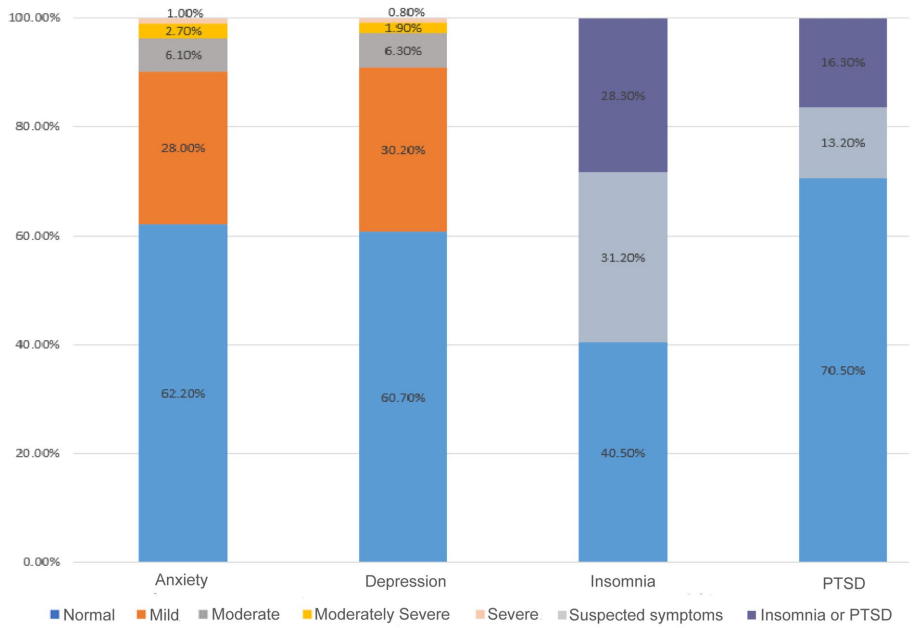

FIGURE 1
The prevalence of anxiety, depression, insomnia, and PTSD symptoms among medical students. PTSD: post-traumatic stress disorder.

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TABLE 2 Independent *t*-tests of sociodemographic characteristics and mental health of medical students.

Variables			GAD-7 scores	PHQ-9 scores	AIS scores	IES-6 scores	PDQ-D scores
Gender	Male	Mean (S.D.)	4.08 (4.38)	4.19 (4.38)	4.82 (3.75)	4.58 (4.30)	4.53 (3.80)
	Female		4.13 (3.71)	4.20 (4.04)	4.71 (3.41)	4.41 (3.81)	4.80 (3.85)
		T	−0.17	−0.03	−0.47	0.65	−1.06
		p-value	0.87	0.97	0.64	0.51	0.29
Grade	Freshman	Mean (S.D.)	3.86 (3.89)	3.87 (3.98)	4.03 (3.90)	4.03 (3.90)	4.65 (3.83)
	Sophomore		4.42 (4.22)	4.59 (4.45)	5.06 (4.18)	5.06 (4.18)	4.67 (3.83)
		T	−2.127	−2.624	−3.872	−3.872	−0.063
		p-value	**0.03**	**<0.01**	**<0.01**	**<0.01**	0.95
Childhood residence	Rural	Mean (S.D.)	4.12 (3.73)	4.55 (4.04)	4.48 (3.98)	4.48 (3.98)	5.24 (3.76)
	Urban		4.13 (4.22)	4.05 (4.31)	4.52 (4.11)	4.52 (4.11)	4.39 (3.83)
		T	−0.038	1.718	−0.139	−0.139	3.233
		p-value	0.97	0.09	0.89	0.89	**<0.01**
Current residence	Rural	Mean (S.D.)	4.14 (3.31)	4.61 (3.65)	4.89 (3.91)	4.89 (3.91)	5.28 (3.55)
	Urban		4.14 (4.20)	4.15 (4.33)	4.44 (4.08)	4.44 (4.08)	4.54 (3.85)
		T	0.027	1.204	1.23	1.23	2.162
		p-value	0.98	0.09	0.22	0.22	**0.03**
Diagnosed with Covid-19?	Yes	Mean (S.D).	4.29 (4.19)	4.35 (4.31)	4.63 (4.10)	4.63 (4.10)	4.84 (3.87)
	No		3.92 (3.81)	3.97 (4.00)	4.47 (4.15)	4.47 (4.15)	4.53 (3.72)
		T	1.033	1.049	0.433	0.433	0.941
		p-value	0.30	0.29	0.67	0.67	0.35

M: Mean; S.D.: Standard deviation; PHQ-9: Patient Health Questionnaire-9; GAD-7: Generalized Anxiety Disorder-7; AIS: Athens Insomnia Scale; IES-6: Impact of Event Scale-6; PDQ-D: Perceived Deficits Questionnaire-Depression. Bold values indicate statistical significance ($p < 0.05$).

TABLE 3 Correlation analysis of age, average monthly household income, mental health, and cognitive function of medical students.

		Age	Average monthly household income	Anxiety	Depression	Insomnia	PTSD symptoms	Cognitive symptoms
Age	R	1.00						
	p-value							
Average monthly household income	R		1.00					
	p-value							
Anxiety	R	−0.05[a]	0.01[b]	1.00				
	p-value	0.13	0.96					
Depression	R	0.03[a]	0.01[b]	0.70[c]	1.00			
	p-value	0.32	0.79	**0.00**				
Insomnia	R	0.03[a]	−0.01[b]	0.48[c]	0.63[c]	1.00		
	p-value	0.38	0.70	**0.00**	**0.00**			
PTSD symptoms	R	0.05[a]	0.04[b]	0.34[c]	0.37[c]	0.33[c]	1.00	
	p-value	0.15	0.19	**0.00**	**0.00**	**0.00**		
Cognitive symptoms	R	−0.01[a]	−0.01[b]	0.45[c]	0.59[c]	0.53[c]	0.31[c]	1.00
	p-value	0.78	0.79	**0.00**	**0.00**	**0.00**	**0.00**	

Bold values indicate statistical significance ($p < 0.05$).
[a]Partial correlation analysis with grade controlled.
[b]Partial correlation analysis with childhood and current residence controlled.
[c]Pearson analysis; PTSD, post-traumatic stress disorder.

Our study showed no significant differences in mental health and cognitive function between male and female students. It might be owing to the similar stresses and negative emotions among male and female medical students as a result of the environment of medical education (23). In addition, sophomores were statistically more likely to experience anxiety, depression, insomnia, and PTSD symptoms

than freshmen. It is possible due to increasing pressure from learning, exams, and career choices in higher-grade students.

It is interesting to note that despite receiving a COVID-19 diagnosis, the mental health and cognitive function of the medical students have not changed significantly. Prior investigations have demonstrated that the COVID-19 pandemic's detrimental repercussions dramatically elevated levels of anxiety and depression (36–38). However, after the long-standing COVID-19 pandemic, the negative impacts, including stigma and fear of COVID-19, progressively subsided in China. Moreover, we speculated that a series of COVID-19-related factors jointly impair the mental health of medical students during the COVID-19 pandemic, including the lockdown measurement, the disruption of clinical training or plans, the excessive learning stress, long screen time due to online learning, less social contact, less exercise, exposure to high-risk environments, and a lack of capacity to handle the unpredictable incident effectively (39–42). The COVID-19 infection is merely one of the factors impairing mental health. Since the COVID-19 pandemic has ended and epidemic policy has been altered, some of the social influences previously mentioned did not pose a threat to medical students anymore.

Medical students with childhood or current rural census registers had significantly higher PDQ-D-5 scores, indicating worse cognitive function compared with urban medical students. Due to the financial, cultural, and educational differences between rural and urban environments, rural medical students may experience an inadaptation to a new life when coming to a university in an urban area (43). The inadaptation may induce concentration and memory decreases, which cause significant differences in PDQ-D-5 scores between rural and urban students. These results indicated the importance of considering the adaptation of rural medical students to the college environment. There was no significant difference between rural and urban students concerning anxiety, depression, insomnia, or PTSD symptoms. The finding of undifferentiated mental health among medical students from rural and urban regions does not corroborate the findings of other rural–urban disparities surveys in China, which generally show that rural college students tend to have worse mental health (depression and anxiety) than urban students (44). However, a prior survey also showed that there was no significant difference in the prevalence of some mental disorders (anxiety, insomnia) between rural and urban students (45). It does not imply that the data collected from regular college students or medical students was "incorrect" or "not replicated." Rather, these inconsistent findings reveal the importance of considering the differences between medical and nonmedical college students in terms of their respective learning environments, educational cultures, and social expectations.

Some limitations are important to consider in light of the current investigation. The survey was conducted in the first and second months after the COVID-19 epidemic instead of during the pandemic. Hence, the variations in prevalence at other time points could not be detected. Moreover, several associated factors, such as the major of medical students, the impact of COVID-19 on students' family, quarantine experience, and history of mental illness, have not been explored in this study. It may interfere with the accuracy of the rates of mental health problems among participants. Also, the participants were recruited from low-grade medical students at Central South University. It is incapable to represent the medical students across the whole country. Therefore, future investigations should recruit medical students from different schools and different regions across the country to constitute a more representative sample.

Overall, the study investigated the current status of mental health and cognitive function in medical students. We analyzed the correlation between sociodemographic characteristics and mental health and cognitive function in medical students and speculated on the potential factors that may induce the significant difference in each group. These findings will contribute to confirming the high-risk populations and providing target interventions to support medical students who suffered various mental and cognitive dysfunctions post-COVID-19 pandemic.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the Second Xiangya Hospital of Central South University (approval number: 047). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JC, ML, ZH, BW, YZ, and BL designed the study and wrote the protocols. JC, ML, JL, YJ, RX, BL, and BW participated in the data collection and organization. JC and ZH undertook the statistical analysis and wrote the manuscript, and then all authors participated in the revision. All authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Impact of forestry on environment and human health: an evidence-based investigation

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There is an increasing interest in the health effects of the forest. Without active participation in forestry, conflicts between the various stakeholders are foreseeable. The impact of forests on human life is unforgettable, and everyone gets enormous benefits from trees and greenery. COVID-19 has caused many changes in human behavior, which needs much attention. Environmental change's impact is considered a better solution and influences human behavior. Scientists around the globe are conducting research experiments on trees and the effect of forestry on human health, which is increasing in terms of social, ecological, and economic services. Trees provide full support to enhance the quality of life and minimize air pollution. Forests must be noticed to get benefits (e.g., carbon storage, fruits, human health considerations, economic benefits, and biodiversity). This research aims to explain the area of forest and health from the perspective of Saudi Arabian forestry and develop strategic measures for the proactive design of this topic. The research entailed expert interviews with forestry representatives and a quantitative survey of medical students. Our findings show that implementing strategic measures, such as establishing a forest and health, improves health and eliminates air pollution. It shows many other establishment and planning strategies, such as the use of professional visitor monitoring, the development of product innovations, the use of digitalization, and the development of integrated forest management.

KEYWORDS

the health impact of the forest, forest and health, Green Care Forest, strategic measures, the recreational function of the forest, sustainability

1. Introduction

Since around 2011, Arabian forestry has been dealing with the health effects of the forest. There are initiatives for this, e.g., Raghadan Forest Park, about "burnout prevention" or rehabilitation. There is a forest of educational accompaniment to the patient's chronic pain and mental stress. In this regard, the Research Center for Forests provides impetus by initiating projects that accompany and promote other offers for further training. As a consistent theme, such references in Arabian forestry still need to be anchored (1, 2). The importance of greenery in times of pandemics and chronic diseases is unforgettable. There are still many diseases that can be cured by herbal medicine, and the impact of greenery on the weather is also very important (3–5).

This topic arouses great interest among the Arabian population. The forest's healing effect is described in many research articles, which simultaneously found the healing bond between man and nature, with much focus on nature (6, 7). Interest in the health effects of the forest is present in Arabian society. It is foreseeable that the flow of visitors to the forest will keep growing in the coming years. Without the active participation of forestry, conflicts with forest visitors are predictable, especially since uncontrolled flows of visitors can severely disrupt the forest ecosystem (8–10).

The first step is introducing Arabian forestry to get an overview of important facts. These include the definition of forest, the forest area and its ownership structures, the basic functions of the forest, and the principle of sustainability. In addition, it gives an insight into the importance of forests for the Arabians. The contribution of the research work is given as follows:

- The study aims to show which challenges are posed by the health effects of the forest for Arabian forestry.
- Out of the analysis will be strategic and practical measures for a proactive design of health and forest in Saudi Arabia from the point of view of forestry.
- The focus is on the balance between the health effects of users and the forest, the forest ecosystem, and the economical use of the woods.

2. Background

Arabian Forestry represents forest owners whose interest groups include forestry training, further education, and research centers. The health effects of the forest are, on the one hand, health promotion and prevention, such as stress reduction and burnout prevention, and, on the other hand, treatments, such as therapy support for mental or associated chronic diseases. The four fields of activity of the forest are defined in the form of key functions in the forest development plan shown. A guiding function is simultaneously the main effect of the forest and is distributed over the entire Arabian forest area. In 2016, the useful function came in first with 61.7%. The second strongest expression has the protection function with 30.1%. The welfare function increases with 7% of the total forest area in third place. The recovery function comes last with 1.2% (1, 8, 10).

The principle of sustainability is the forest's goal, and the forest law's principle is to be green land. This provision has no direct legal force, but it is essential in interpreting the forest law. The forest law is thus a measure and guideline on which the concrete forest law provisions are based on many orientations. With its effects, the forest is a habitat for people, plants, and animals and is an important basis for social, ecological, and economic development in Saudi Arabia. Sustainable management means caring for the health of the forest and using the forest so that its biological diversity, vitality, regenerative capacity, productivity, and potential are continuously maintained. This ensures the forest has ecological, economic, and social functions at all levels without damaging other ecosystems (11, 12).

The three pillars of sustainability are the economic, ecological, and social functions of the forest that are equally distributed. The primary forest policy mandate of the Forest Act is to balance interests between these three factors. A one-dimensional view of the forest contradicts this principle. In Saudi Arabia, sustainable forest management means contributing to climate protection for the health and vitality of the forest and considering economic aspects. In addition, it also promotes biodiversity, which is a protective function, considering social and economic aspects and international responsibility. The following studies show that the forest is important for any country's population and the Arabian population field (13, 14).

In 2012, the authors established a representative survey by the Integral Research Institute. The focus was on the importance of mountains and forests for Saudi Arabia's identity (15–17). Mountains call for 96%, and for 95% of those questioned, forests remain an essential part of the Arabian identity. Notably, 94% consider mountains and forests important for Saudi Arabia (18–20). The lead in the forest ranking is observed, with 100% seeing forests as part of the Arabian identity. Some other cities have the lowest values at 93%. Mountains and forests also have a high identity factor for young people between 14 and 19 years. In the age group of 60–69 years and those over 70 years, the identity factor is highest at 98%.

The second representative study was carried out by a researcher in 2016. Doing so established that more than 90% of the population regularly goes out in nature. Of note, 73% of those questioned prefer to be in the forest, of which 42% do so daily or several times a week. Approximately 75% of the test subjects regularly spend over 30 years in the forest. Of the under-30 age group, 56% are regularly in the forest and 84% of those surveyed like walking or hiking. For 21%, the focus is on collecting mushrooms and berries. This is followed by the activities such as running and jogging with 17%, observing nature/photographing with 13%, and cycling/mountain biking with 6%. For 69%, the recreational value of the forest is important because they enjoy the silence and are able to recharge their batteries. The average length of stay of those surveyed is up to 1 h for 35 and 45% for two or more hours (4, 21).

The study shows that more people are drawn to the forest, so the pressure to use the forest as a natural space also increases. The forest is accessible for everyone to use, so cooperation works. Notably, 91% of the rules asked for binding rules to avoid conflicts between the different interest groups. The importance of forests, lakes, rivers, and mountains will rise in the future; 75% are convinced of that. Also, the raw material wood itself is gaining in importance for 93% of those surveyed, as this renewable resource is a natural raw material and thus serves to protect the climate (22–24).

The sustainability concept of the Arabian forest is based on four pillars: economy, environment, society, and responsibility toward the following generations. As part of the forest strategy, seven forest policy fields of action cover the following subject areas: climate protection, forest health and vitality, productivity and economic aspects, biological diversity, protective function, social and economic aspects, as well as international responsibility and sustainable forest management. The strategic objectives of action field 6, "social and economic aspects", are elaborated in more detail as this deals with the health effects of the forest.

3. Challenges and developments in the forestry

Looking into the future of forest is essential for economic and social development. To recognize ecological developments and derive a forward-looking one from them to plan and implement forest management. Major trends such as climate change, bioeconomy, urbanization, digitization, and health and recreation should also be related to forestry. These trends and their impact on forestry are discussed.

3.1. Climate change

With the result of the project climate scenarios in Saudi Arabia for the first time, the Central Institute for Meteorology has comprehensive data for climate change by 2100. Temperature-related changes will occur by 2050, with an increase in the mean temperature of +1.3°C. The decrease in frost days is up to 2050 between 20.5 and 24.5 days. Similarly, the number of ice days also significantly increases, with daily maximum temperatures of 0.0°C. By 2050, there will be an increase of four to ten hot days (a maximum daily temperature of more than 30°C) in Saudi Arabia (25, 26). There will be significant changes, especially at altitudes below 1,000 m. Concerning precipitation, there are currently no concrete statements. Changes in the total annual precipitation will only become apparent in the future. The climate stress load will generally be high, and the ecological conditions are changing for the forest. The spruce, the main Arabian tree species, comes through endangerment under pressure up to the low mountain range. Harmful organisms are generally a challenge for sustainable forest management. Imports of wood and plants pose a major threat, responsible for introducing non-native insects and fungi, and are favored by the new climatic conditions. The changed climatic influences can reduce the protective effect of mountain forests and reduce natural hazards. Tree species present in the distribution are restricted and will, in the future, also be at home in the mountains (27, 28).

There will also be an increase in the tree line. In silviculture, new and complex challenges are coming to forestry. Silviculture concepts must be considered over a long period of time and simultaneously allow flexibility due to climate change. An essential goal is preserving a site-appropriate variety of tree species in the sense of diversity.

3.2. Bioeconomy

Saudi Arabia is oriented toward international climate goals and pushing for an active climate protection and energy policy. There is a reduction in greenhouse gas emissions by 36% by 2030 compared to 2005. An Arabian bioeconomy strategy was decided in March 2019. The goal is to create products that work with fossil raw materials generated by equivalent ones, based on renewable commodity-based. The bioeconomy strategy is the basis of a bio-based economy that should strengthen the Arabian economy's competitiveness. At the same time, a social rethink should be brought about, and greenhouse gas emissions should be reduced (29, 30).

The forest is a key factor in a positive CO_2 balance. Using wood products, the stored carbon arrives at that time, not into the atmosphere, and at the same time, young trees can absorb the existing CO_2. Wood is to replace other building materials and fuels in the future. The emissions at production, use, and disposal are lower than those of other building materials, such as concrete or steel, effectively reducing CO_2 emissions.

3.3. Urbanization

Another trend is emerging in urbanization, and 55% of the population lives in an urban area worldwide. By 2050, more than two-thirds, or ∼68% of the world's population will live in a city. Cities produce 70% of global greenhouse gas emissions. Due to the rapid development of cities, the danger increases, leading to a climate catastrophe. For these reasons, among other things, urban forestry developed. This form of forestry concerns research and practice dealing with trees, forests, and set-apart green spaces in urban areas. Urban forestry focuses on ecological, economic, social, and aesthetic added value for the city. These include air quality, locations, urban climate, water balance, biodiversity, leisure and recreation, and health and wellbeing. It takes good strategic management and management of the green resource and the involvement of different stakeholders in planning and implementation processes. The growing number of visitors to the exhibition is particularly challenging forest, and the resulting increase in the intensity of use or use activities requires visitor flow control. The networking of the different disciplines and the different interests and demands of the stakeholders are essential tasks within the framework of urban forestry (31, 32).

3.4. Digitalization

Digitization means the increased use of networked digital technologies in forestry. The focus is on networking and self-control. Machines and robots are no longer just executors of work steps. By networking all systems, they can make independent decisions about which components go which way in production. Connected to the Internet, digitization is essential for facilitating a quicker exchange of information between suppliers and buyers. Opportunities in digitization include standardization of interfaces, optimization of processes through data analysis, individual product design, and customer-centric thinking. Forestry 4.0 means, among other things, the real forest stock as a virtual forest, ecosystem, and production site. On the one hand, this novel information, planning, and orientation bases are forestry, and, on the other hand, the citizens are looking for relaxation or are made available to tourists. To make forestry competitive, sustainable, and multifunctional, it is guaranteed that in the wood processing industry, the raw material provides wood efficiently (31, 33, 34).

3.5. Recreation and health

According to Even et al. (35) and Klingmann (36), health has been less important in many countries. Continuously increases the lifespan of people in better health. The search for strength and life energy is the imperative focus to not go through life permanently exhausted and stressed. These demands have a significant impact on people's lifestyles. Balanced nutrition, physical fitness, individual preventive care, and disease prevention characterize everyday life. Know-how about the human body and its associated health keeps increasing. Scientific and empirical knowledge lead to a new

understanding of medicine and thus promote new perspectives and treatment methods (37, 38).

Private individuals increasingly focus on a balanced lifestyle, and companies focus on their employees to create a pleasant working environment through cooperative health. Cooperate health requires clear health management from companies for employees' physical and mental health maintenance. Feeling good increases productivity and sufficient creativity relaxation and is targeted at implementation, leading to a competitive advantage over other companies (39, 40).

Digital networking will completely reshape the topic of health. Open discussions of health issues online, using mobile diagnostic tools and social health movements, will improve communication between physicians and completely redesign patients again.

4. Methods

This research consists of a theoretical and an empirical part. The theoretical part depicts the current scientific view to answer research questions. It gives an overview of Arabian forestry, forestry strategies, development and challenges in forestry, and the importance of the recreational effect of the forest. In addition, the health issue is connected with the discussion of the forest as a recreational space. The connection between forests and health is outlined as part of the topic "Green Care". As a result, the health location of forests and its effects are shown.

The empirical part of the work includes two research methods to approach the answer to the research questions. In the first step, a qualitative research method was chosen. Expert interviews (see Appendix 1) with responsible persons from forestry were conducted in this context. In doing so, their view on the topic of "health effects of forests" was shifted. In the second step, quantitative research was carried out. Many students were asked about their usage behavior of the forest using a questionnaire (see Appendix 2). In addition, questions were asked regarding their awareness of forests and health. Based on the scientific basics and empirical information, measures for Arabian forestry are formulated as recommendations. This course is a critical examination of the knowledge gained from the work.

The interventions to implement the health effects of the forest aim, on the one hand, to promote health and, on the other hand, to improve mental, physical, emotional, and behavioral problems. Among those were prepared by the expert group "Forest for human health and wellbeing", which defines four implementation categories:

i *Forests for health promotion and disease prevention*: this approach includes medicinal forests, medicinal forest paths, regeneration, and wellness paths implemented. In addition, include mindfulness programs and offers for forest bathing and stress reduction.
ii *Forests for therapy and rehabilitation*: within this framework, combinations of nature and psychotherapies, forest therapies or forest therapy hikes and rehabilitation, and forest and social integration.
iii *Forests for direct and indirect health education*: these concepts imply educational outdoor programs such as field trips, thematic excursions, workshops, observation trips, forest schools, and forest play groups.
iv *Forests for tourist recreation*: these include guided hikes, themed excursions, bridle paths, mountain biking, nordic walking, forest vacations, orientation programs, forest museums, etc.

Based on the theoretical principles described so far, the next section presents the empirical research work to link them together and gain new insights.

5. Empirical research work

Qualitative and quantitative analysis is performed to support the research work. The following research questions are derived.

1) What developments and challenges in Arabian forestry are foreseeable in the next 10 years?
2) What are the forest's potential health effects for Arabian forestry in the coming 10 years?
3) (A) What effects do the users of the health effects of the forest have on the ecosystem and the economic use of the forest? (B) Which main user group do the representatives from the forestry represent concerning the health effects of the forest now and in 10 years?
4) Which wishes/needs about the health effects of the forest are there from the user's point of view?

To be able to answer the research questions, two different methodological research approaches were chosen. In the first step, a qualitative research method was adopted as the main method used to provide information. In this context, expert interviews with representatives were conducted. The second step was a quantitative research method as a secondary method to obtain information. For this purpose, a written questionnaire survey with medical students was conducted.

5.1. Qualitative research

Qualitative research is carried out through expert interviews. The expert interview was chosen as the method of qualitative research. Experts are people who have specific, required role knowledge. This is also attributed to them; thus, they have a special competence. This knowledge includes operating knowledge (e.g., processes, rules, and connections), interpretation knowledge (e.g., as an actor in a certain field of discourse), and contextual knowledge about other participants in the investigation. The expert interview takes place in the form of a guideline interview. The expert interviews were conducted based on a few parameters: creation of the guide and implementation of a pre-test, selection of experts, contacting the experts regarding availability and appointments, carrying out the ten expert interviews, transcription of the expert interviews, and evaluation of the expert interviews.

Since the question of the research work from the forestry perspective is illuminated, forestry representatives were selected. They included the following criteria: knowledge of forestry, goals

(e.g., processes, traditions, connections, and developments in Arabian forestry), mapping of different ownership relationships, integrating forestry research and educational institutions, and individuals considered network nodes in the forestry context.

The data were collected through a guided interview. The guide is a structured, written catalog of questions and serves as an orientation during the interview. It contains all the important questions and provides at least a rough structure. The guide is based on three parts: the introductory question; the main part with blocks of questions, topics, and subtopics; and closing and thanks. The interview guidelines within the framework of the expert discussions were based on the research questions (see Appendix 1).

The interviews were then transcribed. The transcription form used depends, on the one hand, on the research methodology and the expectations of knowledge from time to time, as well as on research pragmatic additions. Therefore, it must be clarified in advance what the transcript is being created for and how the analysis should be set up. When transcribing, it needs clarity on what should be written down and the rules based on that. This helps get the job done scientifically to maintain the common thread when reading later loses.

The evaluation of the collected data was carried out according to the methodology of the content-structured qualitative content analysis, as described below, in the context of the master's thesis. The categorization and coding were done in a single, multi-stage process. The main categories were formed deductively by adopting them from the interview guide. A second or third revision defined the subcategories in a mixed form. The main categories differentiated subcategories were partly from the interview guidelines adopted (deductive) or are new in the evaluation context (inductively)—the category-based evaluation gained during the evaluation by comparing and contrasting sophistication, complexity, and explanatory power.

5.2. Quantitative research

The quantitative research approach is object-related and tries to identify explanations and cause-and-effect relationships within this framework. A feature of quantitative research is to deal with social reality through objectively controllable methods. The aim is to define behavior in models, describe numerical data, and make it predictable. We collect data that meets and serves the criteria of objectivity, reliability, and validity to test theories and hypotheses. As a quantitative research method, a written survey using a standardized questionnaire. The survey is very common. It is mainly used when human behavior is not over, and the observations can be recorded, but the test person must provide information themselves. This includes opinions, attitudes, and human behavior. Characteristics of the written survey are:

- The test person needs a personal counterpart when filling out the questionnaire form.
- There is a temporal and spatial distance between the interviewer and the subject.
- The interviewer cannot provide any support in answering the questions permitted.
- There is no certainty that the subject will fill out the questionnaire.

The author follows the following sequence to develop the surveys: creation of the questionnaire, definition of the target group, carrying out a pre-test, revision and finalization of the questionnaire, commissioning a student to carry out the survey, and evaluation and interpretation of the results. The author originally planned the target group of the quantitative survey to collect the "health effects of the forest" within the framework of the expert interviews. The experts' perspectives on who could be a user group were very wide. The general feedback was that potential users of the forest are all humans, and therefore it was impossible to determine a specific target group on this path. However, within the framework of expert interviews, the medical field is often seen as a potentially more interesting future cooperation partner. Therefore, based on the following criteria, the target group of the quantitative survey is defined as potential users of the health effects of the forest, potential future cooperation partners for forestry, and people in a medical facility very close to a recreational forest. The feedback was incorporated, and the questionnaire "Health Effects of Forests" (see Appendix 2) was implemented. In the survey of 2,500 people interviewed, 64% were male and 36% were female between the ages of 23 and 32.

6. Results

6.1. Results of qualitative research

The results of the interviews with the experts are presented below using the five main categories shown: general challenges for Arabian forestry, developments in the area of forest and health, potential for forestry, users and their impact, and strategic and practical actions.

6.1.1. General challenges for Arabian forestry

When evaluating the interviews, four main topics emerged as the future general challenges of forestry emerged.

6.1.1.1. Climate change

Climate change was a topic in all interviews and is referred to as "the" future seen in the challenge of forestry. In the course of climate change, the forest at the same time affected an essential shaper, e.g., the reduction of CO_2 (emissions), or it served as a compensation factor for temperature differences. It will be certain that this change will come, but its reactions will be different. Some of the forest owners are waiting and working as before. At the same time, science is expected to be more well-founded shortly. To be able to provide insights into climate change and develop clear solutions. This means site-appropriate mixed forests tolerate the drought well, especially in the lower altitudes. Some establishments are ongoing due to calamities caused by the bark beetle, which has already started with the conversion and has a reduced proportion of spruce. There is also some helplessness in the forestry sector, especially in companies that have always practiced near-natural forestry and still have suffered major damage from storms, broken ice and snow, and drought.

6.1.1.2. Economic challenges

Climate change is also economically relevant for forestry. The forest owners must watch out for damage caused by bark beetles or extreme weather events that react quickly. Nevertheless, two experts also critically questioned whether or not their own omissions in management contribute to the current economic situation. The recurring catastrophic events strongly influence the wood market. The price of wood is subject to fluctuations that follow. In addition, forestry generally sees itself as having stagnating wood prices and constantly rising wages. Many forestry companies traditionally live from selling wood and hunting, causing them great distress. Diversification in the forestry industry would be important in the future so that forest owners from the timber industry are not entirely dependent.

In addition, the social benefits of the forest, as something taken for granted by society and taken for free by the forest owners, must be made available. Forest companies invest in the company without receiving anything in return, and as the quote below shows, this should change in the future.

6.1.2. Developments in the field of forest and health

In the context of the expert interview, the developments in Arabian forestry were also asked. The most important topics presented.

6.1.2.1. Forestry

Different approaches are currently recognizable under the term Green Care Forest. On the one hand, the health effects of the forest are explicitly understood. On the other hand, the four subject areas of forest education, forest and culture, forest and tourism, and health effects of the forest are subsumed under this term. Few experts had concerns about the time and money forestry would have to invest in establishing itself in the healthcare market. Traditional thinking strongly influences forestry and reacts to these "new" developments in a wait-and-see manner.

6.1.2.2. Collaborations

The health effects of the forest can be established through forestry cooperation. The potential is seen in four possible areas of cooperation:

i Health sector: possible cooperation partners would be, e.g., doctors, therapists, special houses, and clinics.
ii Leisure time: the users are direct cooperation partners, and appropriate projects are developed together.
iii Tourism sector: potential is in cooperation with large hotels or tourism regions, especially regarding quality tourism.
iv Public institutions: shared mountain bike trails or bridle paths are available.

The use of the forest roads is financed by public institutions that are supported and assumed insurance about liability. Region-specific solutions are required. Four experts have rejected public funding because this will make it worse, restricting the right to self-determination of the owner.

TABLE 1 Frequency of carrying out activities in the forest.

Item	Median	Average
I'm in the forest	2	1.66
I relax in the forest	1	1.30
I do sports in the forest	1	1.29
I go for a walk in the woods for an hour or two	1	1.20
I go hiking in the forest for half a day or more	0	0.80
I work in the forest	0	0.27
I meditate in the forest	0	0.10

Annotation: 0, never; 1, less often; 2, several times a month; 3, several times a week; 4, every day.

6.2. Results of quantitative research

The results are clustered according to the topics: stay in the Forest, Activities in the Forest, Effects of the Forest, Requirements for Wellbeing in the Forest, and Awareness of Forest and Health.

6.2.1. Stay in the forest

A stay in the forest was associated with nature by 27%. Included trees and animals played the leading roles. In addition, for example, our own closeness to nature, special smells, and forest noises. The movement is another point of association with the forest for 21% of those surveyed. Walking, running or jogging, and hiking were the most important foregrounds. In addition, cross-country skiing, downhill skiing, and cycling were reported. Other categories were the seasons with 8%, social with 3%, and others with 4%.

6.2.2. Activities in the forest

The test subjects did the following activities: being in the forest, walking in the forest, hiking in the forest, meditating in the forest, doing sports in the forest, working in the forest, and relaxing in the forest. They could answer the following possible questions: daily, several times a week, several times a month, less often or never, or no information. Derived from the median and mean, as can be seen in Table 1, the most common activities of the test subjects are (1) to be in the forest, (2) to relax, (3) to exercise, and (4) to go for a walk. Hiking, meditating, and working are activities that are less practiced in the forest.

Figure 1 shows that 50% of the test subjects are in the forest several times a month, 42% are less often in the forest, and 8% are several times a week. None of the test subjects visit the forest on a regular basis or at all. The topics of recreation and sports show similar residence patterns. Approximately 34 and 32% hold on to this several times a month in the forest. Notably, 44% of those questioned held themselves to this more rarely on-site in the forest. For 16%, neither sport nor recreation is an activity that exercises them in the forest. Approximately 6% of the respondents do this activity several times a week in the forest. Nobody goes to the forest every day for recreation or sport. Approximately 30% take time to walk several times a month, and 58% of those surveyed walk in the

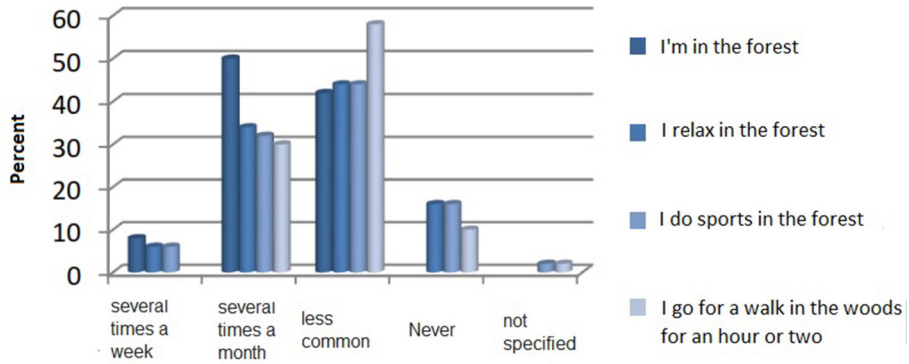

FIGURE 1
The four most common activities carried out in the forest in percentage.

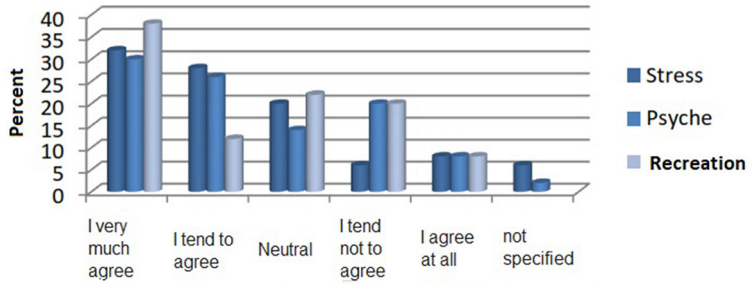

FIGURE 2
The assessment of the positive effects of the forest on stress, psyche, and recreation in percentage.

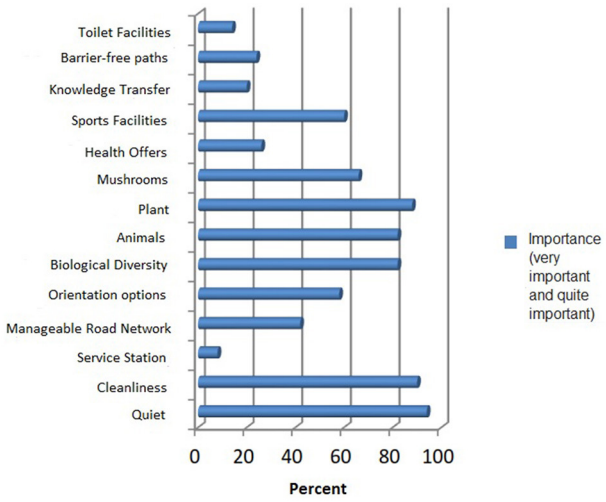

FIGURE 3
Significant elements when staying in the forest in percentage.

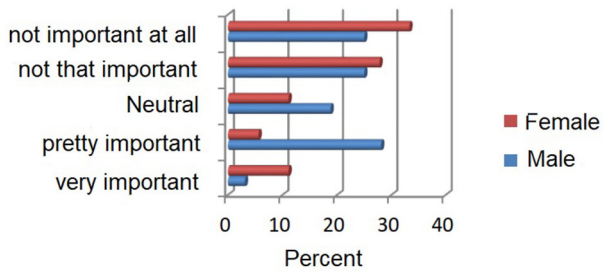

FIGURE 4
Importance of health-promoting offers in percentage, separated by gender.

forest less often. Of note, 10% never go for a walk in the woods. None of the subjects go for a walk daily.

As seen in Figure 2, the first three in a row decelerate in stress, positive for the psyche, and, more importantly, recreation room an agreement of very or the possible answer of more than 50% of subjects. Interesting differences between the male and female subjects are in the subject areas of effect on wellbeing and effect on health. A very or rather positive effect of the forest on general wellbeing, ∼37% of the male test persons agree, and 34% see this neutrally. In contrast, approximately 66% of the female subjects agree very much or tend to agree, and only 11% have a neutral vision. The results of the Mann-Whitney *U*-test show that the information between men and women does not differ significantly on average from each other ($Z = -1.505$, $p > 0.05$).

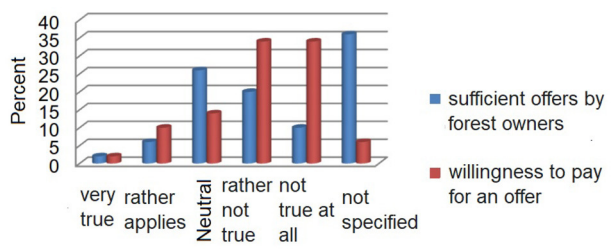

FIGURE 5
Knowledge about the health effects of forests and offers in percentage.

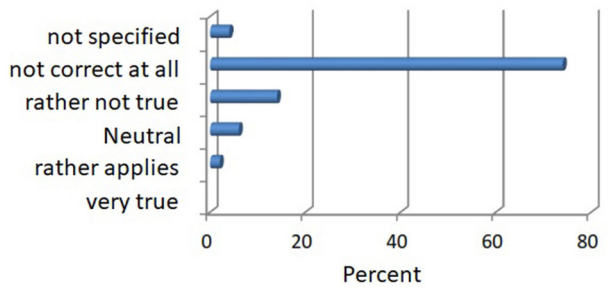

FIGURE 6
Knowledge of scientific studies on the topic of the health impact of the forest in percentage.

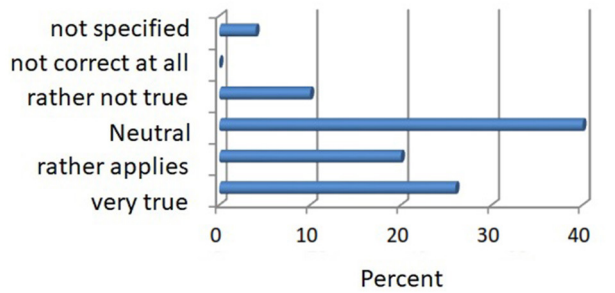

FIGURE 7
The role of the forest in health prevention in percentage.

The calculations of a Mann-Whitney U-test (41) show significant average differences between men and women in their statements about the effect of the forest on their health ($Z = 2.052$, $p < 0.05$). Women vote for the health effects of the forest more than men. A high impact on the forest is healthy in ∼66% of the female test subjects and ∼27% of the male subjects. Approximately 44% of the male subjects tend not to see the importance of the forest for their health, and 11% of the women agree.

6.2.3. Requirements for wellbeing in the forest

When asked the subjects what was particularly important to them during their stay in the forest, 14 subject areas were queried, ranging from 1 = very important to 5 = not at all important or no information could be evaluated.

Figure 3 shows that cleanliness in the forest subjects is most important. For example, 90% of those surveyed rated this as very important (80%) or fairly important (10%). Closely followed by the rest, this one was very important to 66% of respondents and fairly important to 28%. In a row, then stood for the subjects—the fauna and flora of the forest and their diversity—on the importance scale at the top. The sports facilities in the forest are also important.

These were rated as very important or fairly important by 60% of the subjects. The importance of infrastructure, such as orientation options and a walkable network of paths, was ranked in the middle. Barrier-free paths, knowledge transfer, rest stops, and toilet facilities are used by a quarter or classified as less than very or fairly important. Health-promoting offers are considered very important or fairly important by 26%.

Figure 4 shows an evaluation of the health-promoting offers separately by gender. Approximately 30% of the male subjects estimate health-promoting offers as very or fairly important. See this in Only 17% of the female subjects compared this way. The results of the Mann-Whitney U-test show that the differences in the information averaged between men and women are not significant ($Z = -1.003$, $P > 0.05$).

6.2.4. Awareness of forests and health

The last three sections of the survey were devoted to the health effects of forests. In the first step, general information is obtained to determine to what extent the subjects are already familiar with this topic. The response scale ranged from 1 (i.e., very much) to 5 (i.e., not specified at all). To have an equal starting point, it was first defined that what goes into this survey is to be understood as the health effect of the forest. Health effects include health prevention, such as burnout prevention, strengthening of the immune and cardiovascular systems, and other treatments, such as therapy support for psychological or chronic diseases.

More than 50% of the test subjects thought that raising awareness would be important in terms of the health effects of the forest on society, and this item received the highest agreement. Approximately 40% believe that the topic of the future in Saudi Arabia is gaining importance. Just under 20% of those surveyed feel well-informed on the subject. About a quarter of those surveyed would like to join in the future to deal more with this topic, with 38% being neutral on the topic to face. Only 8% of the test subjects consider the offers of forestry in this field sufficient. Notably, 36% could not provide any information at all; 2% have already paid for such an offer; or 12% have, in principle, a willingness to pay for it. Figure 5 shows a comparison of the following items: "In principle, I would be willing to accept the offers pay" and "Arabian forest owners provide sufficient in this regard offers available."

Figure 5 clearly shows that, on the one hand, there needs to be more knowledge about the offers from the forest owners, or these cannot be assessed. However, it is also evident that the willingness to pay for such offers could be higher. In the thematic block "Forest meets medicine", what perspectives and knowledge could the subjects answer with 1 (i.e., very much applies) to 5 (i.e., applies not at all or no information) given? Almost 88% of respondents

said they knew none, and ∼6% were neutral and 4% of the subjects made no statement on this. The statement, "I believe that the forest plays a major role in health prevention for the population," gifts 46% of the respondents very or. Rather their approval, 40% are to the theme across from neutral, and 10% were unconvinced. In addition, 4% could make no statement. For the item "I think the health effects of the forest can be medicinal support treatments," ∼70% of the test subjects were very or rather convinced. Notably, 12% of those questioned were not convinced or not at all convinced, whereas 16% had a neutral approach and 2% gave no feedback.

In the thematic block, "Forest meets medicine", with all the perspectives and knowledge. The subjects (survey form) could answer in a range from 1 (very much applies) to 5 (applies not at all or no information). The results of the surveys are given in Figure 6.

On the topic, "I am aware of scientific studies on the health effects, as per the surveys", 2% of those questioned stated that they were aware of such studies. Almost 88% of the respondents said they knew none, and ∼6% were neutral while 4% of the subjects made no statement on this.

For the other statement, "I believe that the forest plays a major role in health prevention of the population", 46% of the respondents were neutral, 30% were rather applied, 40% approved it as true, and 10% were of that rather not convinced, and 4% could, in addition, make no specific statement. The survey data are given in Figure 7.

That the forest in the vicinity of a clinic affects the wellbeing of the patients promotes, 80% of the test subjects agreed very much or rather; 12% had one neutral opinion; only 6% tended to disagree; 2% were able to do this, giving no information; 78% of the test subjects are very or somewhat of the opinion that forest owners' interesting cooperation partners for medical facilities such as rehabilitation, psychiatry, or health resorts would be; 10% of respondents had a neutral opinion; 8% tended not to share this opinion; and 4% said there was no specification. At the end of the written survey, the subjects were asked to give wishes to the forest owners about the health effects of the forest. Notably, 55 (=100%) different responses were given; these have been broken down into five main categories:

- A large part of the wishes was aimed at the protection and natural conservation of forests, with 38%. These include topics such as promoting biodiversity in the forest, maintaining the forest sustainably, reducing management, and protecting the nature of the forest.
- Another category important to the test subjects is 24% information and communication on the health effects of forests. In addition, there were requests for more information and public relations, clearer offers, concrete cooperation in therapy, and the desire that forestry also expresses what it would need from the population.
- The third category, with 24%, concerns opening up the forest, including, among other things, wishes expressed, such as lifting the driving bans, more sports facilities, and expanding public access to the forests.
- The cleanliness and tourism categories each had 7%. The topics of cleanliness were more cleanliness, improved waste disposal ideas, and litter prevention. Regarding tourism, two thematic areas were forest tourism (primarily motocross and helicopter) and prohibiting or avoiding excessive tourism (mainly for rest, animals, and recreation).

7. Summary of key findings

Up to 47.6% of the Arabian area is covered with forest. A special feature of Saudi Arabia compared to other European countries is that a high share (82%) of private owners exist. Forest development plans are important instruments for forest policy and forest law decisions. Here, the recreational function is limited, with only 1.2% of the Arabian forest areas expelled. The principle of sustainability is the goal and principle of the Forest Act and thus the measure and guideline for its interpretation. The three pillars of sustainability are forests' economic, ecological, and social functions, which have equal rights. The forests have a high identity, creating importance for the Arabian population, with young and older people feeling closely connected to the forest. People are increasingly drawn to the forest, and as a result, higher usage pressure is to be expected in the future.

The United Nations 2030 Agenda is an action plan for planet Earth, and the forest strategy developed as part of this is based on a sustainable approach to forest management (42). Here, too, there is a balance between the economic, ecological, and cultural (social) values of all kinds for present and future generations. At the European level, 40% of the land area is covered with forest. In contrast to the global decline in forests, the Middle East's forest area is increasing easily. Within the framework of the principle of subsidiarity, each country in the Middle East determines its forest policy.

The field of action "Society and economic aspects of the Arabian forests" of the forest strategy are defined as strategic objectives on the subject of the health effects of the forest and give suggestions for strategic measures. This includes, for example, raising awareness about the health effects of the forest, the reconciliation of interests between forest owners and social groups, and health programs on all levels. For silviculture, this means close-to-nature forestry in the longer term, thinking in terms of time, and yet being flexible for the unforeseeable. Another change coming soon is the bioeconomy. Fossil raw materials should go through renewable raw materials to be replaced. One source for this is the forest, which could replace previous building materials and fuels. This is another development Urban forestry theme. In 2050, 68% of the world's population will live in cities. Urban forestry focuses on creating ecological, economic, and social values and generating aesthetic added value for the city. Also, the topic of digitization will keep forestry busy in the coming years. The virtual basics can be used by citizens and tourists looking for relaxation. Recreation and health are another big trend happening in society, and forestry will have an impact. People are looking for strength and life energy, which are also found in the forest.

The Arabian Forest Act stipulates that every person can use the forest for the purpose of recreation. Different values and increasing societal demands on the forest and its effects are breeding grounds for conflicts between user interests. Missing numbers and facts related to leisure and recreational activities in the forest also make good control difficult. It will be integrative and require forest

management to prevent conflicts in advance. Liability issues are also future focal points concerning opening forest roads for various sports, such as mountain biking. Because of nature sports, the pressure on the ecosystem increasingly holds people around the clock in the forest.

The ecosystem services of the forest are geared toward human wellbeing. The central question arises as to how society this added value provided by the forest owners will be able to compensate in an appropriate form. The WHO describes health as perfect physical, mental, and social wellbeing (43, 44). The Arabian health goals are derived from Agenda 2030 and the Health 2020 concept. The 2030 Agenda includes Goal 3 to ensure a healthy life for all people of all ages and promote their wellbeing. The Health Concept 2020 is about improving health and reducing health inequalities.

Contact with nature does not automatically mean Green Care health-promoting interventions with animate or inanimate nature give Green Care its meaning. The aim is to maintain and promote social, physical, and mental wellbeing. International Green Care includes horticultural therapy, care farming, animal-assisted therapy, and natural therapies. Saudi Arabia developed its own Green Care strategy. Green Care Forest is part of Green Care Saudi Arabia and supports people's mental and physical health to maintain, increase, or restore. Green Care Forest is based in Saudi Arabia on four pillars, namely, forest education, forest and culture, forest and tourism, and forest and health. There are legal framework conditions for health offers in forest observation. The main influencing factors on the health effects of the forest are the duration of stay, the type of landscape, the forest aesthetics, the social context, the psychological activities, and possible negative influencing factors. The Health Place Forest has a health-promoting, preventive, and therapeutic effect on people's physical, mental, and social health.

This results in a stress reduction, a strengthening of the immune system, the prevention of cardiovascular diseases, an improvement in sleep quality, and a strengthening of psychological wellbeing and social integration. A qualitative method was used for the empirical research work based on this in the form of expert interviews with representatives of forestry, who also represented the main method simultaneously. As a secondary method, a written questionnaire was used for medical students.

7.1. Findings from the expert interviews

The general challenges of forestry in the next 10 years are linked to climate change, for which there are still no definitive solutions, and the resulting economic developments. In addition, there will be areas of tension between forestry and the requirements of a strengthened society. International and national strategic fields of influence for forest-related strategies will also affect forestry in the coming years.

Regarding the health effects of the forest, forestry and the population perceive very different developments. Green Care Forest will be strong with the recreational function connected; therefore, an economic value currently needs to be discovered for forestry. In contrast to forestry, forest and health care in society are perceived as a strong trend by the media, and popular literature is additionally promoted. Potential is also seen in the health effects of the forest. So it will be assumed that this topic will be an image boost for forestry. It is also recognizable that the health effect of the forest is greater. Product variety for forestry is possible, and thereby, an additional source of income could develop in the form of a niche product. Cooperation would be particularly interesting for the health sector. They will also see an economic benefit since the forest's health effects generally promote or support people's health.

Potentially everyone will be the main user of the health effects of the forest people see, whereby the specific offers must be worked on in a target group-oriented manner. The impact of users on the forest ecosystem is classified as low, provided there is good visitor management and communication. Hunting is an exception to this, as are possible conflicts of interest in this area. The users' impairment in economic use is rated much more strongly. The romantic "transfiguration" of the population always arises, especially when using the wood for bigger conflicts again. More users mean more, while stronger security measures and control rounds increase responsibility.

For a balance between users, the forest ecosystem, and the economy, the following strategic and operational measures should ensure use. One of those is the establishment or expansion of professional visitor management. Next is public relations work to better show the forest owners' services in representing society. The reconciliation of interests will also become an issue in the future important strategic package of measures. This requires cooperation with users and with non-profit organizations. Obtained through urbanization, the products within the framework of the health effects of forests have a chance on the market. It is important to present the added value beyond the recreational effect. Awareness raising and clarification on the subject are also needed internally. The forest owners must be aggressively involved in product development. The research and educational work on forests and health is still in progress in the pioneer phase. There are some initiatives in the research field, but only some result summaries. Networking and various cooperatives are sites of forestry that are especially important in the different regions.

7.2. Findings from the written survey

When asked about a spontaneous connection with the last visit to the forest, "recreation and health" is the top priority. Followed by the second place with the keyword "nature" and the third place with "movement". In the activities practiced in the forest, it is most popular "to be in the forest". This is followed by "recreation" and "sport", also practiced with pleasure. For both positive effects of the forest, the top priority is "deceleration in times of stress, strengthening of psychological wellbeing", and "recovery". The positive effect on "health" is significantly stronger in the female subjects perceived than in male subjects. Pristine forests, mixed forests, and open sparse forests are preferred for a stay in the forest. Monocultures, as well as strongly managed forests, are less in demand.

Awareness raising about the health effects of the forest is considered very important by the subjects. Almost 40% believe this topic will gain importance in the future. Only a fifth of respondents

feel informed about the subject. Only very few subjects could assess forestry offers on forest and health handover. At the same time, there needed to be more willingness among the subjects to accept such offers. Only one test subject was allowed to conduct scientific studies on this topic. Almost half of the respondents believed that the forest in preventive healthcare plays an important role. More than two-thirds of respondents believe the forest's health effects support medical treatments. Just as many assume that a forest in a medical facility's environment promotes patients' wellbeing. Two-thirds of the test subjects also see forest owners as interesting cooperation partners in the medical field. When it comes to the wishes of forestry about the health effects of the forest, the protection and preservation of natural forests are ranked first. However, the wish came true after more information and communication. Peer was also wishing for more opening of the forest for visitors.

7.3. Interpretation of the findings

The Arabian Forest Strategy 2020+ was created as part of a broad-based participatory process. This enabled the integration of many different stakeholders and is considered a showcase project in terms of participation. The health effects of the forest are made explicit, in contrast to the international strategies mentioned in the Arabian forest strategy, and testify to innovation potential. At the same time, the strategy is also a compromise. Many strategic subject areas and measures will be named without clear responsibilities and time frames for implementation. As a result, the strategy loses traction and liability for the responsible stakeholders. In addition, the question defined indicators. The number of projects says nothing about raising awareness of the importance of the health effects of forests. The impression was created that the forest strategy, which is a very good instrument, needs to be more relevant to practice in forestry, which is necessary for a strategy.

The term Green Care is strategically and in terms of content strongly influenced by agriculture. Green Care Forest still needs to have a clear profile in forestry. It means different things at different levels. So is what the Federal Ministry for Tourism and Sustainability understands by this forest education, forest and culture, forest and tourism, and forest and health. As part of Green Care Forest, the Federal Research Center for Forests relies on the classic definition and understands the educational, health-promoting, and social activities and interactions between humans, animals, and nature. As part of Green Care Forest, images that only deal with forests and health set the focus. These different interpretations indicate a missing coordination process between the different responsible parties. In addition, it is unclear who is responsible for this topic, as the so-called "process owner" pulls. A successful brand establishment needs a clear profile with a clear definition and objective, and a responsible person who drives the brand forward.

The forest development plan is an important forest policy instrument in Saudi Arabia. As part of this, only 1.2% of the area is designated recreational forest. Here it becomes clear how unattractive the recreational forest is for the Arabian forest owner. The Forestry Law of 1975 opened a door in Saudi Arabia. All forest owners are obliged to admit people to their forests for recreational purposes without receiving any financial compensation. The tendency of forest visitors is increasing, and with it, the target group's requirements. The question of liability has yet to be satisfactorily clarified, and forest owners are in danger of being sued. This causes forestry rather than defense mechanisms to develop. The tension between private property and public interest comes to bear here. For forestry, the question arises as to what else is additionally reasonable. In the context of the expert interviews, this question was repeatedly discussed.

Both international and national forest management strategies have one focus on sustainable forestry. This means managing the forest in such a way that, currently and in the future, the forest's economic, social/cultural, and ecological functions are secured. This goal definition runs as a red thread through the research work. Economic, ecological, and social goals are often divergent and carry the potential for conflict. In the future, it will need more participatory ways in the form of cooperation, joint projects, and decision-making processes with the different stakeholders. Balancing interests thus becomes an important management task. In addition, it takes courage in forestry; these new ways of working together try out because they also have much innovative power. Due to climate change and the resulting disasters such as storms, frost, and drought, the economic situation of forest enterprises is very challenging. It follows unplanned high costs to reforest and maintain the areas.

In addition, the price of wood is stagnating or is subject to negative fluctuations. Traditional sources of income from timber production and hunting often need to be increased. In both expert interviews, it was mentioned again and again that there are additional mainstays needed to be able to survive economically in the long term. Such a foothold could be one of the health effects of the forest. The added value of a "health place forest" for forestry is not yet tangible or visible. The previous pilot projects show the first possibilities on a "small" basis but are mostly financially unattractive. They find many imitators in forestry. In an economically difficult situation, building something new simultaneously requires much courage and an attractive vision, which still needs to be developed for the health effects of the forest, among other things. Many forest companies also need more resources and know-how for their product development.

The forest ecosystem is severely affected by climate change. A climate-friendly forest will primarily be associated with a silvicultural conversion of the forest, and diversity is seen as an important success factor. More people in nature and all that around the clock also put greater pressure on the different ecosystems in the forest. How visitor flows affect this currently needs to be assessed. Visitor monitoring concerns forest visits in Saudi Arabia, limited to national or nature parks. There needs to be more data and facts on how forest visitors affect the regions, e.g., in urban areas or tourist areas. As a result, an important basis for argumentation about politics and society is to enforce forestry interests.

Research on the "health effects of the forest" is available in Saudi Arabia but is still expandable. In the expert interviews, it became apparent that within the framework of the training sector in forestry, there needs to be more knowledge on this topic. The exception here is a certificate course, "Green Care Forest".

Parallel to forestry, a new education market is emerging, e.g., forest bathing or mindfulness training in the forest. Forest health education is pure knowledge transfer and therefore does not require a qualification. This means that the education market is about forests and health and is open to all people who feel qualified to do so. In the medical sector, as the survey of medical students became visible, hardly any knowledge was conveyed about the health effects of the forest. So that the topic of forests and health can be seriously brought to society, more investments are needed in education, including state-recognized training standards. Forestry cannot do this alone, but only by implementing cooperation, e.g., with the health sector.

Potentially everyone will be the main user group for the forest as a healthy location people perceived. This has the advantage that a broad target group can be addressed here. Individual forest owners will focus on certain groups of people who need to specialize to market themselves in a region. Cooperation partners will be needed for larger projects like establishing a healing forest. Since the forest ownership structure in Saudi Arabia is very fragmented, larger projects are becoming more common. Setting goals can be a big challenge. Become a cooperation partner on the part of the forest experts in the medical and soft tourism fields. In addition, it should also be mentioned that the medical students, in the context of the written forestry survey, are also an interesting cooperation partner to imagine. In addition, companies would also be interesting cooperation partners, as they are interested in Cooperate Health to keep their employees healthy.

Health has a high priority in society itself, and the trend is going in the direction of self-optimization of overall health and the search for strength and life energy. This search will strongly impact people's lifestyles in the future. The forest as a health location has many prerequisites regarding the vision of the future WHO. The Arabian health goals are also contrary to the forest's health effects. The health sector's trends, visions, and goals have less of an eye on forestry. But they have potential, for example, in the context of digitization. In forestry and the health sector, digitization will take hold to a large extent in the next 10 years and completely realign previous work. New synergies can be created here, e.g., in the form of apps between the green and white areas. It was interesting that the medical students started their last stay in the forest, which connected health and recreation in the first place. So at the test, people have a positive experience, and they have the connection between the forest and health produced intuitively.

In the specific questioning about the effects of the Waldes, primarily stress reduction, strengthening of psychological wellbeing, and recovery receive a high level of approval. This results in a similar picture as in the scientific studies on the health effects of the forest and corresponds to the trend toward the search for strength and life energy. It is striking that, especially for female subjects, the effect of the forest on health has a higher force attribute. The Mann-Whitney U test shows significant results. This matches with the scientific evidence that women, on the health effects of the forest, react more strongly than men, especially in the context of stress reduction.

In a survey of an older target group, they would probably have infrastructure facilities or a walkable network of paths that have a different meaning than for the young medical students. Therefore, on-site framework conditions always tailor the offers to the target group. The preferred forest landscapes of the user group surveyed are untouched. Forests, mixed forests, open and light forests, and well-groomed forests. This also corresponds to criteria regarding forest aesthetics. All of these are not very popularly managed forests. This underscores the tension between forest owners and visitors; it was also a hot topic in the expert interviews. Forest owners must live from forestry and are dependent on forest management. Forest visitors want to experience untouched nature that is well-cared for. These different interests will work together in the future. The majority of the students surveyed think that

- Awareness-raising about the health effects of the forest would be important in the future.
- The topic of the health effects of the forest gain becomes important.
- The forest plays a major role in health prevention.
- The forest supports medical treatments.
- The forest in the vicinity of a clinic affects the patient's wellbeing.
- The forest owners are interesting cooperation partners for the medical facility.

This feedback is encouraging and shows that the positive effects of the forest are valued. There is always a noticeable openness to forests and health for medical students. However, the target group surveyed needed more information about the health effects of the forest. At the open, feedback regarding the wishes of the forest was communicated, and more information and communication about it were needed. More information and communication are also issues in forestry itself. Concrete offers are few for the subjects of the written survey known, and only a few can imagine paying for such offers. In addition, the respondents would like a more restricted approach to forestry management and greater forest opening. This topic is reflected in the expert interviews from another perspective. The forest is called something that is taken for granted. This reduces the willingness to pay for products. Therefore, it is used in the forest and health products and needs services that have an additional benefit beyond the recreational function.

8. Conclusion

Forestry is characterized by a strong traditional way of thinking shaped over the centuries. Forestry products are primarily timber production and hunting. The understanding of forestry for the desires of forest visitors is only available to a limited extent. New things are often met with great reservation. Innovation and development are currently playing a minor role. There are, of course, innovations, for example, about the efficiency of wood production, but hardly in the area of product innovations.

8.1. The forest strategy

It requires a definition of packages of measures with clear responsibilities and binding time frames. A possible model would be, e.g., strategy "leisure and recreation in the forest". A second possibility would be that the stakeholders involved in the forest

strategy take responsibility for implementing packages of measures in the form of binding self-commitment takeovers. Another important step would also be the development of meaningful indicators, e.g., awareness or competence expansion of the health effects of the forest in the population map, for example, through representative surveys, a number of state-recognized training and further education measures, health professions in forest and health and others.

Forest and health brand requires developing and establishing a "Forest and Health" brand in Saudi Arabia. There is also one associated with this professional communication strategy for forestry (internal), for the Arabian population (to the outside), and for possible cooperation partners, e.g., for the health sector, tourism, or company. This also requires clear process ownership. Potential candidates include the Chamber of Agriculture, the Arabian Forstverein, and the Federal Ministry for Tourism and Sustainability.

8.2. Facts and figures

Another important measure is the establishment of exemplary visitor monitoring in urban areas or strong tourist regions. The aim is to assess the motives, behavior, and activities of the forest visitors, e.g., their impact on the ecosystem and forestry use, to assess more precisely. Over and beyond, visitor monitoring represents an argumentation aid about politics and society to better represent one's interests. It also serves as a basis for decision-making for effective visitor management.

8.3. Innovation and development

Forestry establishes or participates in innovation clusters in the regions, aiming to develop innovative products and economically relevant services jointly. It is binding cooperation at the regional level between different research areas and partners from industry and science.

8.4. Digitization

Development of a digital platform on the subject of forest and health in which people find out about products and services throughout Saudi Arabia and information about the health effects of the forest. At the same time, she could serve as an exchange platform between forestry and forest visitors. In addition, apps on the subject of forests and health can be linked to concrete instructions developed.

8.5. Education

In training and further education for forest experts and owners, investments should also be made in health professions concerning forests and health. As a first step, the goal could be to raise awareness and develop communication skills for this topic with these target groups. In a second step, people need to be empowered for this field of work, for example, within the framework of advanced courses for health professions or those trained in forestry.

Integrative forest management is built up in urban areas or tourist regions. The participation of stakeholders in decision-making and development processes is in focus. This can already be done when creating forest development plans or joint projects on forest and health. In addition, professional communication and public relations are required. Furthermore, it requires mediation skills to balance economic, ecological, and social interests and solve conflicts. It would be important for Arabian society to develop incentive systems for creating forest owners to address the topic of "health effects of the forest", which is easier to establish in forestry. The theoretical processing of the topic and the ten expert interviews provide a good insight into and overview of the current challenges in forestry on the topic of the health effects of the forest. In addition, possible connections within the framework of Green Care Forest between the health sector and forestry are presented, and ideas for strategic and operational measures are derived.

The validity of the quoted scientific studies on "health effects of the forest" is not always comprehensively scientifically proven. Further studies in a randomized, controlled form are planned for future topics. The quantitative research part is due to the small number of participants that need to be regarded as representative. Still, it only gives an impulse about the user behavior of young adults undergoing medical training. The selection of this group was interesting because future cooperation with partners in forestry could be possible. Making statements about user behavior would require a much larger sample representing the Arabian population.

In the proposed research, other interesting topics arose that are essential for forestry research and should be further explored. These findings are the limitations of the current work and should be further investigated in the future and deepened in the context of further research. A few research areas could be as

- innovative product development for the health effects of the forest in the context of digitization, e.g., in the form of apps.
- establishment of a "Forest and Health" brand in Saudi Arabia.
- integrative forest management in the urban environment.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AA: Formal analysis, Funding acquisition, Investigation, Methodology, Writing—original draft, Writing—review and editing, Conceptualization.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1260519/full#supplementary-material

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Potential impacts of Russo-Ukraine conflict and its psychological consequences among Ukrainian adults: the post-COVID-19 era

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Background: Since February 2022, the nation of Ukraine has become entangled in an escalating conflict that erupted after coronavirus outbreak fostering a situation of indeterminacy and precariousness, which adversely affected several facets, especially psychological well-being. However, there is a lack of empirical evidence on the psychological well-being of Ukrainians during the Russo-Ukraine war, as well as their coping strategies in response to the war's repercussions. Consequently, this investigation endeavors to explore the prevalence of symptoms associated with depression, anxiety, stress, and insomnia and to correlate these symptoms with Ukrainians' effective coping mechanisms during the ongoing war.

Methods: An online survey was administered in Ukraine from June to August 2022 due to the ongoing Russo-Ukraine conflict. The survey employed a quota sampling technique, targeting 2,664 individuals (≥18 years). Out of the total sample, 1,833 valid responses were obtained, yielding a response rate of 68. 81%. Depression, anxiety, and stress were measured using the depression, anxiety, and stress scale-21 (DASS-21), while the Pittsburgh sleep quality index (PSQI) was utilized to evaluate insomnia symptoms. In addition, Brief-COPE was adopted to evaluate the coping mechanisms of the selected study participants.

Results: Of 1,833 Ukrainian adults, 60.5% had symptoms of stress; 62.4% of them reported symptoms of anxiety; and 58.2% reported symptoms of depression. Symptom criteria for insomnia were found in about 21.8% of the study sample. The factors of sex, living area, area occupied by Russian forces, and having older adults and children in the house were statistically significant with symptoms of depression, anxiety, stress, and insomnia. The productive coping strategies of self-distraction, using instrumental support, planning, and behavioral disengagement, were observed as statistically significant with four psychological constructs.

Conclusion: The study outcomes highlight a substantial prevalence of symptoms related to depression, anxiety, stress, and insomnia attributed to the accumulated consequences of ongoing conflict and the COVID-19 outbreak. The aforementioned findings emphasize the imperative of providing healthcare services and facilitating effective coping strategies among Ukrainians amid the ongoing war.

KEYWORDS

Russo-Ukraine conflict, COVID-19, coping mechanism, DASS-21, PSQI, depression, anxiety, stress

Introduction

The impacts of warfare extend to both combatants and civilians, leading to detrimental physical and psychological manifestations for both groups. War can result in various deleterious physical consequences such as mortality, harm, sexual assault, starvation, diseases, and disabilities. Additionally, individuals exposed to war may experience post-traumatic stress disorder (PTSD), which further exacerbates the overall impact on their well-being. Depression and anxiety are among the emotional manifestations experienced by individuals (1, 2). The deleterious and alarming impact caused by the belligerence of armed conflict disrupts the lives of individuals and fractures relationships and families, thereby inducing profound emotional turmoil within affected individuals and communities (3).

The historical trajectory showcases the severe ramifications on national welfare resulting from armed conflicts (4). One of the consequential outcomes encompasses enduring physical and psychological detriments experienced by both children and adults. Numerous empirical investigations focusing on the broader populace have delineated a discernible rise in the occurrence and prevalence of mental afflictions stemming from armed conflicts. The confluence of the Russo-Ukrainian war with the ongoing global pandemic appears to exert an amplified impact on the well-being of Ukrainian individuals, particularly in terms of mental health (4). In light of the understanding that the healthcare system within Ukraine possessed considerable attributes, yet bore certain vulnerabilities, it can be inferred. During the prevailing coronavirus pandemic, which has notably imposed a substantial strain on healthcare systems and practitioners, such assaults possess the potential to generate even more severe consequences for Ukraine. According to data collected by the Surveillance System for Attacks on Health Care (SSA), a total of 157 instances of attacks on healthcare facilities were documented as of April 2022. The targeted assaults on crucial health infrastructure impede numerous individuals from accessing essential health services, despite their urgent and pressing health requirements. The impact of this traumatic experience is not solely confined to individuals who directly underwent it, but it can also be transmissible from parents to their subsequent offspring through nuanced yet inheritable modifications to the genome (5).

The present confluence of the Russo-Ukraine conflict and the prevailing coronavirus outbreak has fostered an exacerbation of the obstacles confronting the younger segment of the Ukrainian population (6). The ongoing pandemic that commenced in 2020 has potentially precipitated a heightened state of depression in individuals who are witnessing the warfare, consequently amplifying the preexisting psychological distress caused by the persisting threat of coronavirus. Hence, it was anticipated that there would be a positive correlation between individuals experiencing depression while observing the war and their perceived danger derived from the outbreak of coronavirus disease (7). The acquisition of weaponry among young males exposes them to more perilous and detrimental environments. Despite possessing robust immune systems, the coordinated efforts of these individuals present a potential danger to them. Young females are residing in densely populated shelters. Adolescents face an increased susceptibility during the process of flight, as they encounter the dismantling of their shielding interpersonal connections and encounter a lack of healthcare resources. The public health of individuals is at risk for both transmissible and non-communicable illnesses, as a consequence of diminished accessibility to medical care and resources, alongside diminished rates of inoculation and screening (1, 8).

Previous pieces of evidence have shown that exposure to terrorism and conflicts can have disastrous effects on the psychological well-being of individuals, leading to various mental health issues including depression, acute stress reactions, personality changes, cognitive impairments, anxiety disorders, and PTSD. This holds for those directly involved in the conflict such as combatants and veterans, as well as innocent civilians like refugees and the general population (9–12). The armed confrontation between Ukraine and Russia has already resulted in an assortment of psychological concerns (13, 14). An empirical investigation that evaluated the psychological well-being of the Ukrainian people prior to and following the recession discovered the proportion of people with indicators of stress increased by 5% from the year 2012 to 2016 (15). In connection with this, a survey conducted on 2,203 young Ukrainians who had been relocated across Ukraine in 2016 discovered that 32% of people had PTSD, 22% experienced depression, and 17% dealt with anxiety (10, 11).

As individuals undergo traumatic events and endure the stress of a prolonged war, there is a heightened likelihood of mental health issues and a decline in psychosocial well-being (16–18). However, there has been limited evidence conducted on the occurrence of psychological symptoms in the Ukrainian populace during the Russo-Ukraine conflict. According to scholarly research conducted in 2022, a notable incidence of war anxiety, reaching an approximate rate of 77.7%, was documented among the population of Polish citizens and Ukrainian refugees residing in Poland (19). A survey study was carried out among the student body and staff members of four universities in Ukraine, wherein a substantial occurrence of emotional states of anger, depression, nervousness, loneliness, and exhaustion was observed with a prevalence rate of 76.9, 84.3, 84.4, 51.8%, and 86. 7%, respectively (20). Hence, there arises a pressing need to investigate the incidence of mental illnesses within the broader populace amidst the Russian incursion into Ukraine.

The act of coping can be described as the conscious endeavors made to avert or mitigate threat, harm, and loss, or alleviate the ensuing anguish (21). Qualitative investigations have explored an array of coping mechanisms that Ukrainian individuals have embraced in response to Russia's incursion. In a recent study, researchers conducted interviews with Ukraine refugees to investigate the various coping mechanisms employed to navigate their challenging circumstances. The findings indicated that establishing ongoing communication with their separated loved ones, actively acquiring accompaniment, and engaging in prayer emerged as the primary coping strategies (1, 2, 22). Additionally, *Khraban* analyzed discourses extracted from posts and comments shared on social media platforms by individuals residing in northern Ukraine throughout the initial 15-day period of the conflict. The research revealed a fluctuating utilization of coping mechanisms, specifically emotion-focused and problem-focused strategies, employed by civilians. These coping mechanisms served the purpose of expressing and alleviating negative emotions while simultaneously striving to mitigate the impact of distressing situations. Furthermore, they aimed to foster positive emotions such as benevolence and solidarity among the affected individuals (23).

The present study primarily focuses on the employed productive coping strategies, given the minimal mention of maladaptive coping methods involving substances like drugs and alcohol. This study aims to examine the efficacy of diverse coping strategies employed by the general populace of Ukraine in alleviating psychological symptoms amidst the ongoing conflict. The examination of coping strategies reveals categorization into two primary types: problem-focused and emotion-focused coping (24–26). In the realm of psychology, problem-focused coping pertains to the active endeavors made to eliminate the underlying problem at hand. Prior research has underscored the significance of problem-focused coping mechanisms in the context of managing wars or terrorism. In postwar Afghanistan, it was observed that Afghan individuals sought out enhanced sustenance, improved housing conditions, and augmented income levels (11). Emotion-focused coping pertains to efforts aimed at mitigating distress through the modification of problem perception or evaluation. This study aims to examine the impact of coping strategies employed during the Ukraine war. To procure a comprehensive and diverse collection of Ukrainian adults, we implemented a quota sampling method to explore their manifestation of depression, anxiety, stress, and insomnia, alongside their employed coping mechanisms.

Methods

Study design and population

Bearing in mind the ongoing conflict between Russia and Ukraine, prospective participants were sent invitations electronically, spanning from June to August 2022. The online survey was administered to attain a nationwide reach and ensure the secure participation of individuals through the utilization of mobile devices. To gather a representative sample of Ukrainian adults, we employed the non-probabilistic technique of quota sampling. This technique is widely recognized as a prominent technique for conducting online surveys in regions lacking access to a probabilistic panel (27, 28). In the present study, the utilization of quota sampling based on age, sex, and marital status proved to be a successful and feasible approach for procuring a representative sample of the Ukrainian population during the specified period. The survey was conducted utilizing the Ukrainian language and encompassed a cover page that provided a comprehensive explanation of the study's scientific aims, ensuring that all participants provided their informed consent before commencing the survey. Out of the cohort of 2,664 adult individuals who were duly invited to partake in the examination, we have successfully procured a cumulative amount of 1,833 legitimate and relevant replies, yielding a commendable response rate of 68.81%.

Ethics

The present survey received ethical approval from the Institutional Review Board of the university. In adherence to ethical principles, informed consent was duly procured from every participant involved in the investigation. Furthermore, stringent measures were adopted to safeguard anonymity and maintain strict confidentiality of the data acquired during the research process. No incentives were provided for the participants.

Instruments

In this study, various socio-demographic attributes of the participants were collected encompassing age, sex, marital status, ethnic background, educational attainment, population of the respondents' residential area, occupational status, presence of Russian forces in their locality, occurrence of active conflicts in the area, household size, as well as cohabitation of children and senior individuals within the same household.

Depression, anxiety, and stress scale-21 (DASS-21)

The present study employed a set of 21 self-report questionnaires, specially crafted to evaluate the extent of severity of the fundamental symptoms associated with Depression, Anxiety, and Stress. This assessment tool has been previously validated and is widely acknowledged within the scholarly community (29). The administration of the survey may be carried out by the respondents themselves or facilitated by a third party. Every query must be addressed. The study utilizes a four-point Likert scale to ascertain the ratings of respondents, with each item assigned a numerical score ranging from *0* to *3*. The total score for each participant on the Depression, Anxiety, and Stress scales is obtained by multiplying the sum of seven pertinent items by two. Each scale is subsequently divided into subscales consisting of two to five items each.

The Pittsburgh sleep quality index (PSQI)

The assessment of sleep quality (symptoms of insomnia) was conducted utilizing the PSQI, which comprehensively assesses sleep quality through the examination of 19 indicators categorized into seven distinct dimensions (30). The evaluated dimensions consist of subjective sleep disturbance, sleep quality, use of sleeping medication, sleep latency, sleep duration, sleep efficiency, and daytime dysfunction. In this study, a Likert scale with 4 levels was employed to assign scores ranging from 0 to 3 for each dimension, resulting in a total score between 0 and 21. A higher score on this scale indicates poorer sleep quality among the participants.

The coping orientation to the problem experienced inventory (brief-COPE)

An adapted version of Brief-COPE was used to assess the coping mechanism of Ukrainian individuals (31). The questionnaire has been utilized in several investigations about conflict and is adequate for measuring coping mechanisms (32–34). The index measures 10 coping mechanisms using two items on a 7-point Likert scale, with 1 being strongly disagree and 7 being strongly agree.

The translation of all instruments was carried out in accordance with pertinent guidelines, in the Ukrainian language. Two autonomous

translators were engaged in the process, wherein the adaptation encompassed a direct translation from English to Ukrainian language. This was followed by a reversed translation, and subsequently, psychological interviews were conducted with an initial set of participants. The reversed translated iteration was juxtaposed with the genuine rendition and any complications encountered throughout the process were deliberated upon and effectively tackled prior to the culmination of the conclusive rendition of the instruments.

Statistical analysis

In order to gain insight into the respondents' attributes and the prevalence ratio of symptoms related to mental well-being, an initial implementation of basic descriptive analyzes was conducted. Pearson's correlation analysis was also performed to detect the multicollinearity among the study variables. Before we put the variables into the regression analysis, we checked for the assumptions. Shapiro–Wilk Test has been used to test the normality of the data. Subsequently, a series of multivariate analyzes were performed to evaluate the relationships between coping mechanisms and symptoms of mental well-being. The aforementioned cutoff rates were employed to categorize the four psychometric constructs as binary variables. In a parallel manner, logistic regression was executed to explore the association between coping strategies and mental health outcomes. We also tested the reliability of the constructs using Cronbach's alpha in the present investigation. All the analyzes were performed using SPSS (v26) with a significant threshold of <0.05 and < 0.01.

Results

Table 1 displays an overview of the sociodemographic characteristics of the study participants. According to the findings, the respondents exhibited an average age of 32.6 years, wherein a majority proportion of 61. 05% represented the female gender. The vast majority of the population comprises individuals affiliated with the Ukrainian ethnic group, accounting for approximately 98.85% of the total demographic composition. A total of 13.58% of the participants were found to reside in the region previously occupied by Russian forces, while 16.42% were identified as residing within the active conflict zone, as indicated within the context of the entire study sample. The findings indicate that a significant majority of the respondents, specifically 72.45%, reported residing within urban localities. Conversely, a remainder of 27.55% indicated their place of residence as rural regions. A majority of participants, comprising 59.7%, reported being married or in a cohabitating relationship. Following this, a substantial proportion of 35.7% indicated being single, while a smaller minority of 4.6% reported being divorced, separated, or widowed. The findings reveal that a majority of participants, constituting 75.99%, possessed a university degree or higher educational qualifications, while a smaller proportion of 24.01% were either students in school or college. Regarding the individual's employment statuses, the majority of the participants constituted students (40.82%), followed by employees (39.72%), self-employed (81.3%), unemployed (64.9%), and pensioners (4.86%) Based on the statistical data, it can be observed that a significant proportion of households, amounting to 55.48%, consists of family

TABLE 1 The social-demographic characteristics of study participants ($n = 1833$).

Demographic variables	*n* (%)	Significance
Age	32.6 ± 11.9	<0.001
Sex		0.04
Male	714 (38.95)	
Female	1,119 (61.05)	
Marital status		0.04
Single	654 (35.7)	
Married/cohabiting	1,094 (59.7)	
Divorced/separated/ widowed	85 (4.6)	
Ethnicity		0.04
Ukrainian	1814 (98.85)	
Russian	19 (1.15)	
Educational level		<0.001
School/college level	440 (24.01)	
University and above	1,393 (75.99)	
Location		0.172
Urban	1,328 (72.45)	
Rural	505 (27.55)	
The area occupied by Russian forces		<0.001
Yes	249 (13.58)	
No	1,469 (80.15)	
Partially	115 (6.27)	
Active fighting in the area		<0.001
Yes	301 (16.42)	
No	1,446 (78.89)	
Do not know	86 (4.69)	
Employment status		0.01
Employed	728 (39.72)	
Unemployed	119 (6.49)	
Self-employed	149 (8.13)	
Student	748 (40.82)	
Pensioner	89 (4.86)	
Household size		0.03
1–2	101 (5.51)	
3–5	1,017 (55.48)	
6 or more	715 (39.01)	
Children at home		0.02
Yes	1,216 (66.34)	
No	617 (33.66)	
Older adults at home		0.02
Yes	1,035 (56.46)	
No	798 (43.54)	

Significance level at $p < 0.05$ and $p < 0.001$.

sizes ranging from 3 to 5 members. The majority of participants indicated the presence of older individuals, such as parents or grandparents, residing within the same residence (56.46%) Meanwhile, a significant proportion of the sample acknowledged having children under the age of 18 coexisting within their household (43.54%).

Table 2 displays the descriptive statistics and the analysis of the interrelationship among the four psychometric constructs. The study's outcomes indicate that anxiety and stress were the predominant symptoms observed among the adult population in Ukraine. The average values of anxiety and stress were found to be 7.68 and 11.45, respectively, accompanied by standard deviations of 3.96 and 4.48. Notably, depression exhibited a mean of 9.26 and a prevalence rate of 58.2%. In contrast, the indications of insomnia were observed to be widespread, with a prevalence rate of 21.8%, accompanied by an average value of 12.11 and a standard deviation of 0.88. The bivariate analysis of the chosen study variables demonstrated a fundamentally symmetrical and unimodal distribution, indicating the absence of any non-linear relationships among the variables. The observed associations did not surpass the threshold of 0.7, indicating the absence of any discernible indications of multicollinearity.

Table 3 represents the outcomes obtained from multivariate logistic regression analyzes conducted to explore the potential correlations between chosen demographic factors and coping strategies on psychometric indicators. The findings suggest that there was a higher likelihood of male participants displaying indications of stress, whereas female participants demonstrated a greater propensity for experiencing symptoms of anxiety, depression, and insomnia. Participants residing in urban regions displayed elevated levels of insomnia in comparison to individuals residing in rural regions. Individuals living with children reported a higher prevalence of insomnia, whereas those residing with older adults individuals displayed an elevated manifestation of depressive symptoms. One possible reason for this phenomenon could be attributed to the heightened vulnerability experienced by children and the older adults, who are regarded as particularly susceptible demographics during times of conflict. As a consequence, individuals coexisting with these individuals demonstrated a higher prevalence of mental health symptoms, potentially attributed to their additional obligations in providing care not only for themselves but also for their aforementioned counterparts. Individuals residing in regions under Russian occupation reported heightened levels of anxiety.

Furthermore, the outcomes indicate a negative correlation between the utilization of instrumental support and behavioral disengagement coping strategies and the presence of stress symptoms. The utilization of self-distraction as a coping mechanism exhibited a negative correlation with symptoms of anxiety, depression, and insomnia while demonstrating a positive connection with symptoms of stress. There was a substantial linkage between active coping and anxiety symptoms, while a positive relationship was noted between planning and symptoms of insomnia. The utilization of instrumental support exhibited a positive correlation with anxiety symptoms. The findings of this study also demonstrate a substantial correlation between behavioral disengagement and the manifestation of depressive symptoms and sleep disturbances.

Discussion

The present study represents the first comprehensive investigation of the associations between depression, anxiety, stress, insomnia, and coping strategies among Ukrainian citizens within a more diverse sample size. The advent of armed conflict generally poses a significant risk to the mental well-being of non-combatant individuals as a whole. In comparison with the incidence rates documented in 2016 regarding anxiety and depression (35), a comparatively higher proportion of Ukrainian adults experienced a diverse array of psychological manifestations, most notably depression, and anxiety (36). The obtained findings align with earlier research, which indicated a rise in the occurrence and frequency of psychological manifestations, among United States military veterans who have engaged in combat (37). Similarly, these results mirror the documented impacts of the Russo-Ukrainian discord on the mental well-being of the general population (15).

In response to the detrimental effects of the conflict, we further endeavored to explore the coping mechanisms embraced by Ukrainians and their correlation with the manifestation of psychological disorders. The results of our investigation indicate that the act of pursuing instrumental support exhibits a negative correlation with stress and a positive relationship with anxiety. This phenomenon may be attributed to the heightened propensity of individuals experiencing anxiety to actively solicit instrumental support. Based on empirical findings, it is apparent that instrumental social support coping emerged as a prominent coping mechanism employed by individuals residing in Israel in response to traumatic stress and the symptoms of PTSD after acts of terrorism. According to empirical research on the coping mechanisms used by Ukrainian military troops in counterterrorism missions, post-traumatic symptoms and the coping technique of soliciting social support have shown a negative correlation (38, 39).

TABLE 2 Descriptive statistics and bivariate correlation among psychometric constructs of the participants.

	Construct	Participants with symptoms *n* (%)	$\bar{X} \pm SD$	1	2	3	4	α
DASS-21								
1	Depression	1,066 (58.2)	9.26 ± 3.67	–				0.85
2	Anxiety	1,143 (62.4)	7.68 ± 3.96	0.463	–			0.84
3	Stress	1,108 (60.5)	11.45 ± 4.48	0.328	0.471	–		0.84
PSQI								
4	Insomnia	399 (21.8)	12.11 ± 0.88	0.356	0.392	0.502	–	0.86

DASS-21, Depression, anxiety, and stress scale 21; PSQI, Pittsburgh sleep quality index; $\bar{X}$, Mean; SD, standard deviation; α, Cronbach's alpha.

TABLE 3 Multivariate logistics regression analysis of demographic characteristics and coping strategies with psychometric constructs.

	DASS-21						PSQI	
	Depression	*p*-value	Anxiety	*p*-value	Stress	*p*-value	Insomnia	*p*-value
	B (SE)		B (SE)		B (SE)		B (SE)	
Age	5.64 (0.17)	<0.001	−6.12 (0.10)	<0.001	−5.46 (0.09)	<0.001	−3.28 (0.06)	<0.01
Sex	−0.39 (0.02)	0.128	0.79 (0.01)	0.072	1.19 (0.01)	0.207	2.01 (0.02)	0.074
Marital status	−0.41 (0.11)	0.173	0.91 (0.09)	0.185	0.21 (0.08)	0.199	−1.12 (0.07)	0.183
Ethnicity	1.23 (0.17)	0.343	−2.43 (0.12)	0.502	−1.14 (0.09)	0.086.		
Educational level	1.29 (0.07)	0.526	−1.07 (0.09)	0.418	−1.11 (0.07)	0.080	1.09 (0.08)	0.106
Location	1.09 (0.08)	0.117	1.82 (0.07)	0.612	2.13 (0.06)	0.293	3.45 (0.06)	0.112
The area occupied by Russian forces	−2.51 (0.12)	0.248	2.31 (0.17)	0.092	1.75 (0.81)	0.195	1.12 (0.71)	0.305
Active fighting in the area	−0.29 (0.24)	0.311	1.24 (0.18)	0.521	−0.76 (0.18)	0.439	1.13 (0.10)	0.181
Employment status	0.82 (0.05)	0.632	1.92 (0.11)	0.821	2.02 (0.05)	0.128	2.39 (0.04)	0.220
Household size	−1.19 (0.06)	0.761	1.37 (0.07)	0.093	0.78 (0.04)	0.405	2.28 (0.05)	0.543
Children at home	−0.88 (0.06)	0.192	−0.96 (0.12)	0.165	1.13 (0.09)	0.532	2.13 (0.06)	0.153
Older adults at home	−0.53 (0.11)	0.082	−0.63 (0.09)	0.323	3.18 (0.08)	0.452	−0.29 (0.20)	0.732
Brief COPE								
Adaptive coping								
Active coping	1.23 (0.07)	0.520	4.22 (0.04)	<0.05	2.16 (0.08)	<0.05	−2.29 (0.10)	0.093
Planning	1.68 (0.06)	0.074	2.61 (0.05)	0.521	2.93 (0.05)	0.603	4.14 (0.06)	0.543
Positive reframing	0.29 (0.05)	0.422	−0.73 (0.04)	0.428	−0.56 (0.04)	0.158	0.37 (0.04)	0.507
Humor	−1.16 (0.04)	0.119	1.34 (0.03)	0.106	1.78 (0.03)	0.217	−0.34 (0.04)	0.072
Acceptance	2.23 (0.05)	0.669	−2.18 (0.04)	0.354	−2.01 (0.04)	0.348	0.28 (0.11)	0.145
Religion	−2.17 (0.03)	0.105	2.43 (0.03)	0.532	−0.11 (0.04)	0.532	2.01 (0.03)	0.098
Use of emotional support	2.49 (0.09)	<0.05	−2.19 (0.07)	<0.01	−2.26 (0.07)	<0.01	−1.17 (0.10)	<0.01
Use of instrumental support	−3.41 (0.03)	<0.05	3.56 (0.02)	<0.01	2.16 (0.04)	0.088	2.07 (0.21)	0.191
Maladaptive coping								
Self-distraction	3.13 (0.06)	0.03	4.12 (0.04)	<0.01	2.69 (0.06)	<0.05	−3.19 (0.06)	<0.001
Denial	−1.46 (0.08)	0.165	−2.34 (0.09)	0.097	2.54 (0.08)	0.017	−2.13 (0.03)	0.429
Venting	−2.65 (0.05)	0.669	−3.47 (0.06)	0.532	−2.56 (0.04)	0.348	−3.42 (0.05)	0.165
Behavioral disengagement	−5.69 (0.02)	<0.001	2.83 (0.02)	0.087	3.18 (0.03)	<0.01	3.84 (0.10)	<0.01
Pseudo R^2	0.11		0.12		0.12		0.10	

DASS-21, Depression, anxiety, and stress scale 21; PSQI, Pittsburgh sleep quality index; S.E, standard error; α, Cronbach's alpha.

Furthermore, our investigation revealed a positive correlation between active coping strategies and symptoms of anxiety. Similarly, we observed a positive association between planning strategies and symptoms of insomnia. Previous studies have reported that individuals tend to employ active coping and strategic planning mechanisms as a means of managing stressful situations. In another investigation it was discovered that Ukrainian students employ proactive coping mechanisms, specifically through the utilization of problem-solving planning, to navigate stressful situations successfully (40). Positive reframing was not observed to be correlated with symptoms linked to psychological well-being among Ukrainians in the early stage of the Russo-Ukraine conflict. A study conducted by Dickstein et al. (41) revealed that individuals residing in Israel employed a positive reframing strategy, namely, adopting an optimistic outlook on life, as a means to cope with stress induced by the persistent threat of terrorism. Another study demonstrated that the relationship between watching the war and depression is fully mediated by cognitive interference, suggesting that it is not the act of watching the war itself, but rather its connection to cognitive interference, that is linked to depression. There exists a positive relationship between denial, the act of refusing to acknowledge or accept the reality of the coronavirus threat, and depression (7). The lack of adoption and efficacy of this

measure among Ukrainians can potentially be attributed to the rapid and intense escalation of the war, which may have hindered their ability to perceive it in a positive light.

Behavioral disengagement coping, characterized by the act of relinquishing efforts to cope with stressful situations, exhibited an unfavorable correlation with stress symptoms. However, its association with depression and insomnia was observed to be positive. The utilization of self-distraction coping strategies was found to have a positive correlation with indications of stress, yet a negative correlation with anxiety, depression, and insomnia symptoms. These outcomes are aligned with the results reported in previous investigations. In an investigation, it was observed that following the implementation of a threshold level of interventions, the adoption of avoidance and distraction methods was significantly associated with reduced post-Persian Gulf War stress responses (34). According to another research, it was found that engaging in activities to distract their thoughts proved to be beneficial for individuals displaced from Chechnya in managing their symptoms related to stress (42). Turetska (38) observed a noteworthy correlation between symptoms of PTSD and the tendency to employ problem-avoidance strategies in a cohort of Ukrainian military personnel. In a scholarly investigation conducted by researchers, it was identified that among a cohort of 3,294 adults, a specific coping strategy exhibited potential as a longitudinal mediator between major depressive disorder stemming from various traumatic events and generalized anxiety disorder (43). The outcomes of the present investigation also observed that emotion-focused coping mechanisms, along the lines of humor, religion, and seeking emotional support, displayed no apparent correlation with psychological symptoms among the Ukrainian population. The adverse circumstances resulting from war often engender a challenging environment wherein individuals find it arduous to engage in humor or derive amusement from the prevailing circumstances. The non-association between emotional support and religious coping, as identified in past conflicts to alleviate symptoms of mental illness such as anxiety, depression, or PTSD, was observed in the context of Ukraine, implying a lack of psychological symptom mitigation through these factors (11, 42, 44, 45).

The findings of our study indicate that there exists a positive association between the implementation of problem-focused coping mechanisms by Ukrainians and their mental health symptoms. Conversely, the effects of emotion-focused coping strategies displayed a varied pattern, displaying positive correlations with certain symptoms while demonstrating negative relationships with others. According to Hobfoll et al. (46) the implementation of emotion-focused coping strategies may yield significant effectiveness in handling highly demanding circumstances in the initial stages. Emotion-focused coping was discovered to be correlated with a subsequent rise in both the occurrence and intensity of post-traumatic symptoms among warriors over an extended period following combat engagement. The plurality of effects observed in our investigation necessitates further long-term investigations to elucidate the underlying causal associations between psychological disorders and emotion-focused coping mechanisms. However, the interconnectedness of naturally acquired coping mechanisms and psychological problems underscores the necessity of employing professional behavioral therapies in Ukraine.

Regrettably, the current repertoire of interventions provided by mental healthcare practitioners and centers in Ukraine frequently lacks a foundation in empirical evidence introducing a critical concern. According to a survey carried out in Ukraine in 2017, data suggests that mental illness has a prevalence rate of 33% within the population. However, a mere 4.9% of individuals grappling with such conditions are reportedly undergoing treatment (47). There is a substantial prevalence of psychological symptoms observed in Ukraine and Eastern Europe (48). Also, several obstacles impede individuals' access to healthcare services, encompassing geographical remoteness, social stigma, feelings of shame, limited knowledge and awareness, substantial financial burdens associated with therapy, apprehension towards mental healthcare, and skepticism of the medical services. The ongoing coronavirus outbreak has already posed an immense burden on the healthcare network and healthcare personnel, rendering them susceptible to heightened stress levels. The Russian invasion has worsened this predicament, aggravating the existing challenges faced by the public healthcare network. Enhancing the professional development of physicians and psychologists by offering additional education and training in the field of mental health could potentially yield beneficial outcomes. Moreover, the provision of supplementary outreach services to individuals in Ukraine could potentially prove advantageous. The continuation of conflicts is probable, inevitably resulting in significant emotional anguish. Further exploration into empirical investigations is required in order to facilitate healing, foster resilience, and integrate cultural competence, with the aim of delivering suitable and efficacious mental health services to prospective war survivors.

Limitations

Several limitations need to be recognized when it comes to the interpretation of the findings of the current study. The current study is grounded in a cross-sectional design conducted amidst the ongoing Russo-Ukraine conflict. Consequently, it is imperative to acknowledge that we are limited in our ability to establish a causal connection between psychological manifestations and coping mechanisms. It is conceivable that a circular association would exist between coping strategies and symptoms, wherein coping strategies exert an influence on symptoms, which subsequently instigate alterations in coping. There is a need for further investigation to elucidate the specifics of this association and establish the probable course of causation in prospective longitudinal investigations focusing on examining the links between symptoms of psychological manifestations and adopted coping mechanisms over an extended period. The present study directed its attention toward examining efficacious coping strategies. Strategies such as substance abuse, namely through drugs and alcohol, possess the potential to be counterproductive measures when attempting to handle the threat imposed by warfare. Subsequent inquiry may explore maladaptive coping mechanisms, such as substance and alcohol misuse, to ascertain their effects and potential interventions.

Conclusion

An upsurge in psychological manifestations has been attributed to the simultaneous effects of the coronavirus outbreak and the

Russo-Ukraine conflict. Given the prevalence of societal prejudices and restrictions, psychological wellness is frequently neglected in Ukraine; this propensity is exacerbated in times of conflict and epidemics, emphasizing the necessity for boosting essential backing for preventative services for emerging psychological demands and actions aimed at enhancing accessibility to care for ongoing and developing psychological disorders.

Our research offers preliminary insights regarding psychological health indicators such as depression, anxiety, stress, and insomnia amidst the upheaval as a consequence of the Russo-Ukraine invasion. Ukrainian individuals subjected to the Russian invasion have displayed a range of effective problem-solving coping mechanisms, including active coping and planning, in addition to adopting emotion-focused approaches such as seeking instrumental support, practicing behavioral disengagement, and resorting to self-distraction as means to mitigate these challenges related to psychological wellbeing. The aforementioned statistics highlight the imperative nature of providing expert medical care and psychotherapist services to individuals amidst times of invasion.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The study was conducted according to the guidelines of the Declaration and approved by the Ethics Review Committee of Prince Sattam Bin Abdulaziz, institutional review board, Deanship of scientific research (Ref: PS-04/25/2022). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

AK: Conceptualization, Formal analysis, Investigation, Methodology, Writing – review & editing. AA: Funding acquisition, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Health perception and restorative experience in the therapeutic landscape of urban wetland parks during the COVID-19 pandemic

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Introduction: The effects of restoration and inspiration in the therapeutic landscape of natural environments on visitors during the COVID-19 pandemic have been well-documented. However, less attention has been paid to the heterogeneity of visitor perceptions of health and the potential impacts of experiences in wetland parks with green and blue spaces on visitors' overall perceived health. In this study, we investigate the impact of the restorative landscapes of wetland parks on visitors' health perceptions in the context of the COVID-19 pandemic.

Methods: In our survey, 582 respondents participated in an online questionnaire. We analyzed the respondents' health perceptions in terms of latent class analysis, used multinomial logistic regression to determine the factors influencing the potential categorization of health perceptions, and used structural equation modeling to validate the relationships between health perceptions of different groups and landscape perceptions of wetland parks, restorative experiences, and personality optimistic tendencies.

Results: The results identified three latent classes of health perceptions. Gender, marital status, education, occupation, income, distance, frequency of activities, and intensity of activities were significant predictors of potential classes of perceived health impacts among wetland park visitors.

Discussion: This study revealed the nature and strength of the relationships between health perception and landscape perception, restorative experience, and dispositional optimism tendencies in wetland parks. These findings can be targeted not only to improve visitor health recovery but also to provide effective references and recommendations for wetland park design, planning, and management practices during and after an epidemic.

KEYWORDS

health perception, restorative experience, therapeutic landscape, COVID-19 pandemic, latent class analysis, structural equation modeling

1. Introduction

The COVID-19 pandemic has had a profound impact on human society (1). Although control measures have calmed the outbreak, they have also exacerbated mental health problems (2, 3). A growing body of literature underlines the importance of extended psychological and physical health distress during the COVID-19 epidemic (4, 5), which is considered a public health concern. Although people may suffer from many adverse effects on their health during an epidemic, such as fear of viral infection, prolonged isolation, and other complex factors, people with optimistic dispositions tend to ease stress and anxiety caused by the epidemic because of their positive psychological cues, improve their physical health, seek social interactions to fulfill their social roles, and maintain their intrinsic mental and emotional health (6, 7).

Natural areas can provide an escape from mundane urban life (8). Many studies have suggested that natural connectivity in a therapeutic landscape provides a comfortable and healing environment for tourism and recreation (8–10). This reduction in mental and physical resources can be offset by access to a therapeutic environment (11, 12). Thus, visits to wetland parks, which are special parks with therapeutic landscapes in urban areas, may effectively prevent anxiety and depression caused by short- and long-term quarantines and lockdowns in natural environments (13–15). Wetland parks in urban areas improve water and air quality, support biodiversity, and promote human comfort (16, 17). However, less attention has been paid to the important role of therapeutic landscapes in urban wetland parks in healing, restoring, and maintaining human health (18–20). Therefore, it is paramount to understand how the experience of wetland parks benefits visitors' perceived health. This study attempts to broaden the knowledge of how the experience of wetland parks' therapeutic environment affects people's health perceptions.

In addition, evidence shows differences in individuals' perceptions of their health status based on gender, age, personality traits, and cultural background. These heterogeneities can directly influence visitors' attitudes and behaviors toward health issues. Highly preferable and stimulating landscapes in wetland parks can improve people's mental state and promote physical wellbeing. However, factors such as social background and personal preferences differ between individuals, leading to differences in their subjective perceptions of health. Therefore, understanding the heterogeneity of visitors' health perceptions during their visit to wetland parks is important for improving their health status. Heterogeneity in health perceptions has become an important issue in several fields, including social psychology and behavioral medicine. However, academic research on health perception in wetland parks is lacking. Therefore, further research is needed to understand the heterogeneity in the health perceptions of wetland park visitors and guide the planning and management of wetland park landscapes.

The following section proposes a comprehensive framework through which we explore the nature and strength of the relationships between people's perceived health and their experiences with the therapeutic landscape in terms of landscape perception, restorative experiences, and dispositional optimism tendencies in wetland parks. This is followed by a description of the methods used for data collection and modeling approaches, including latent class analysis (LCA) and structural equation modeling (SEM). Based on these results, the key findings and discussion are presented in Section 4. Finally, conclusions and implications are presented in the last section.

2. Conceptual framework and hypothesis

The landscape comprises physical, social, and symbolic aspects (21). People perceive the physical landscape as the interaction between individuals and the natural and built environments (22). The park, which is characterized by highly visible mowed areas, open water, and flourishing planting mixtures, provides a diverse and picturesque landscape for visitors to enjoy (23–27). It is attractive to walkers, dog walkers, and cyclists and provides space and opportunities for physical activity (28, 29). The social aspect of the landscape is perceived by individuals when they interact socially, and it includes a wide range of themes related to public attitudes, values, behaviors, and activities (30). The social aspect of the landscape benefits social integration by providing public spaces for activities that generate broad social connections and overcome people's feelings of social isolation and exclusion (31, 32). The symbolic landscape, as a psychological cue, is associated with the public's belief in the healing characteristics of the therapeutic environment (33–36). For example, national parks in the United States function prominently in American culture and religion, with symbolic meanings of 'inspiration', 'stability', and 'healing' (37).

By visiting urban wetland parks, people can access the therapeutic landscape of nature with water, diverse vegetation, open lawns, and bright flowers, resulting in substantial improvements in mood, cognitive function, and mental health (38–40). A temporary escape from the dreary pressures of work and life and immersion in nature can satisfy the need for fresh air, sunlight, water, and food, thus facilitating a restorative experience (41). Moreover, comfortable public spaces in wetland parks allow visitors to interact socially, independent of their socio-economic status (31, 32). Wetland parks provide uncrowded and undisturbed spaces for visitors seeking solitary experiences, such as meditation and independent thinking, in natural environments. In addition, visitors can achieve psychological benefits through horticultural activities that ultimately improve their perception of restoration (40).

According to the literature, an individual's health is influenced by environmental factors, sociodemographic characteristics, and psychological traits (18, 39, 42, 43). Dispositional optimism is a positive psychological trait often associated with good health and relief from stress and anxiety (44). Therefore, experiences in wetland parks may have an impact on health perception, which may vary among individuals with various sociodemographic backgrounds and behavioral activities.

Previous studies have indicated a diversity in individuals' health perceptions (45, 46). However, it cannot be simply determined *a priori* from the relevant observed variables because the unobserved heterogeneity in an individual's perception is not

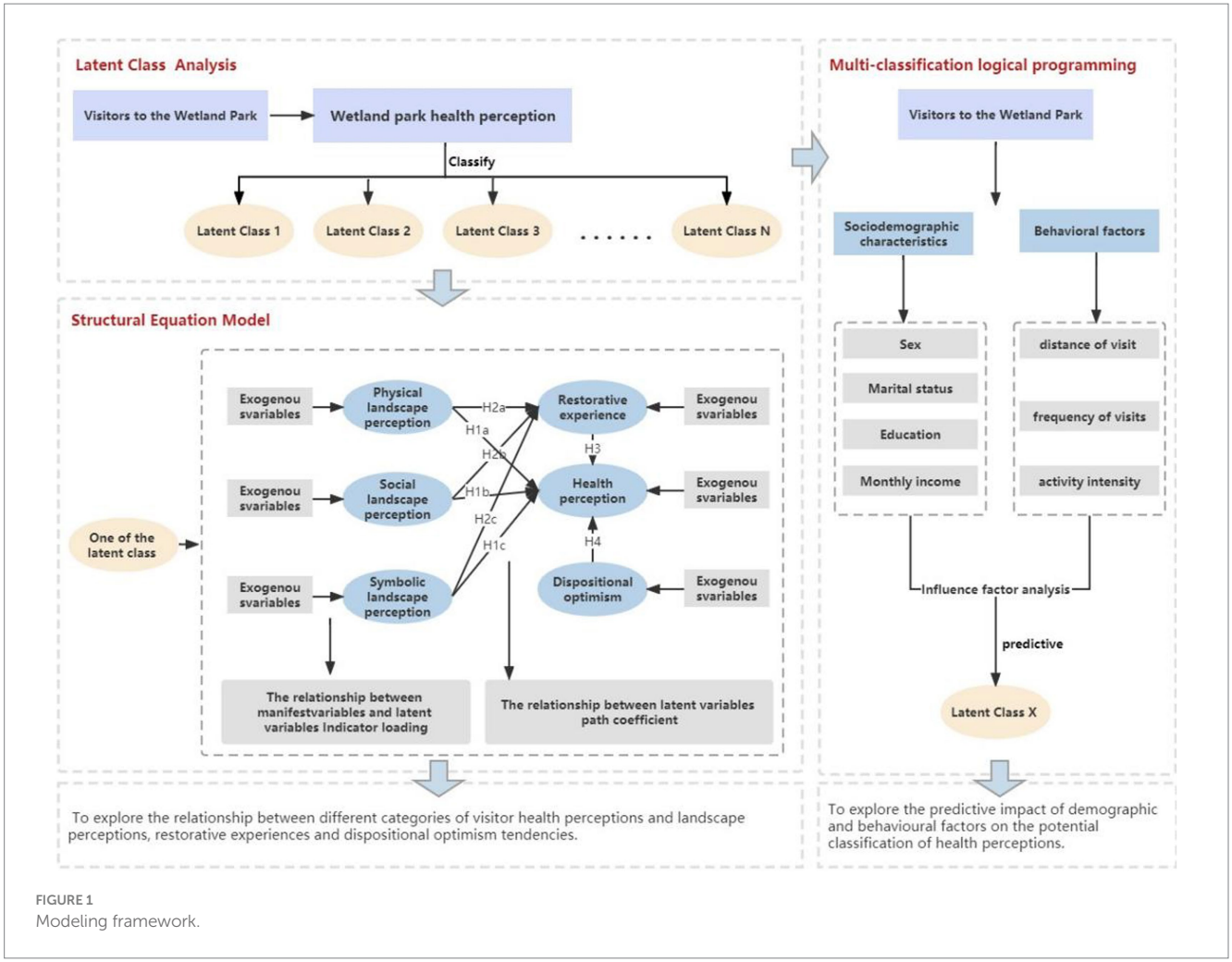

FIGURE 1
Modeling framework.

necessarily captured by the variables preconceived and specified by existing theoretical and conceptual models, but it can exist outside of the previously identified variables (47). For example, the results of various studies on gender differences in health perceptions in wetland parks are mixed: Some studies have found no significant differences in health perceptions between men and women who visited wetland parks before and after the outbreak (39), while others have shown that women who visited nature reserves felt healthier than men (48). It is imperative to classify heterogeneous visitors into multiple homogeneous groups and identify appropriate treatments for wetland park planning and design. A new modeling framework (Figure 1) was developed to accurately capture the health behavior patterns and core characteristics of different populations.

3. Methodology

3.1. Methods

LCA is a finite mixture model. It is a statistical method that allows associations between exogenous indicators to be explained by an intermittent latent class so that associations between exogenous indicators are explained by the latent class and thus maintain their local independence (49, 50). LCA is used to identify unobservable classes within a population that may have similar health perceptions. It provides a medium through which results can be expressed in terms of probabilities rather than fixed deterministic conclusions (49, 51). The relationships between individuals' landscape perceptions, restorative experiences, and dispositional optimism tendencies were analyzed separately for different classes of visitors.

The mathematical expression for LCA is shown in the following equation:

$$\pi^{AB..ZX}_{ab..zt} = \sum_{t}^{T} \pi^{A|X}_{at} \times \pi^{B|X}_{bt} \times \cdots \times \pi^{Z|X}_{zt} \times \pi^{X}_{t} \qquad (1)$$

where $\neq^{AB..ZX}_{ab..zt}$ is the joint probability of a health-perceiving visitor taking the values of a,b..z for different field attributes. $\neq^{A|X}_{at}$ is a conditional probability indicating the conditional probability that the value of the health perception field attribute A of a health perception visitor is the given value of a given health perception visitor if the visitor belongs to class t of the latent variable. $\neq^{x}_{t}$ is the latent class probability, which indicates the probability that a health-perceiving visitor belongs to potential class t.

The latent class probabilities are to satisfy equation (2).

$$\sum_{t} \pi_{t}^{x} = 1 \tag{2}$$

Conditional probability reflects the strength of the relationship between latent and exogenous variables. The formula used is as follows:

$$\sum_{a} \pi_{at}^{A|X} = \sum_{b} \pi_{bt}^{B|X} = \cdots \sum_{z} \pi_{zt}^{Z|X} = 1 \tag{3}$$

SEM is a general statistical approach used to assess the relationships between observed and latent variables (52), and it can estimate specific path coefficients based on identified latent classes.

The equation of the measured model is as follows:

$$X = \Lambda x \xi + \delta \tag{4}$$

$$Y = \Lambda y \eta + \varepsilon \tag{5}$$

where equations (4) and (5) are the exogenous and endogenous indicators, respectively. Λ is the relationship between inventory and latent variables, and δ and ε are measurement errors.

The structural model is a path diagram reflecting the relationship between the effects of potential variables and is formulated as follows:

$$\eta = B\eta + \Gamma \xi + \varsigma \tag{6}$$

where η is the endogenous latent variable, ξ is the exogenous latent variable, and B denotes the effect of the exogenous latent variable on the endogenous latent variable. Γ denotes the effect of some endogenous latent variables on other endogenous latent variables, and ζ is the regression residual.

3.2. Data collection

The questionnaire consisted of seven sections: (I) socio-demographics, (II) physical landscape perception, (III) social landscape perception, (IV) symbolic landscape perception, (V) restorative landscape perception, (VI) health perception, and (VII) the C-WEMWBS Warwick-Edinburgh Positive Psychology Scale. The Health Perception Scale was derived from Ware's General Health Perception Scale (53). The Restorative Experiences Scale was derived from Korpela (54), Korpela (55), and Von Lindern et al. (56). The Dispositional Optimism Scale was derived from the Warwick-Edinburgh Mental Health Scale (WEMWBS). Questionnaires were distributed across China *via* an online platform on 15 February 2022. Before the official questionnaire was distributed, a sample of wetland park visitors was taken for a pre-survey to verify its suitability and check for any ambiguities so that the questionnaire could be revised and improved. The survey was continued only if the respondents indicated their experience of visiting a wetland park. Table 1 shows the questionnaire form.

4. Results

4.1. Descriptive statistics

Table 2 presents the socio-demographic characteristics, socio-economic status, and dwelling conditions of the respondents. Slightly more female visitors than male visitors participated in the survey. Of the respondents, 18–45-year-olds were the majority, followed by those aged 45 years. In terms of marriage, 63.1% of the visitors were unmarried, and 36.9% were married. Approximately 76.1% of the respondents had a bachelor's degree. Students were predominant in the sample population, accounting for 34.9% of respondents, while employed individuals accounted for 34.2%. The respondents' monthly income is denoted in Chinese Yuan (CNY), and the income of more than one-third of the respondents did not exceed 3,000 CNY. Regarding housing tenure status, most respondents lived in dormitories or with their families, and approximately 70% of respondents did not own property. Most of the respondents had lived in the local area for more than 3 years. Nearly half of the respondents reported that their neighborhoods were under semi-containment or full containment as a result of the outbreak. Of these, 13.1% were strictly confined to their homes during the outbreak and could not move freely within their neighborhoods. In addition, 44% of them were required to record their temperature when entering and leaving the neighborhood.

Table 3 lists the factors related to transportation. More than half of the visitors traveled more than 5 km to the wetland park, and only 8.4% traveled less than 1 km; thus, the wetland park attracts many visitors who live far from it. In terms of transport choice, 41.6% of visitors chose to travel by taxi or car, with the fewest visitors choosing to travel by motorbike or bicycle, accounting for 11% of the sample size. The respondents who visited wetland parks once every 6 months accounted for 47.1% of the sample size, and only 2.6% visited wetland parks weekly. For most of them, the main purpose of visiting was to rest and relax. In terms of activity intensity, 84.2% of visitors chose low-intensity activities, whereas only 2.1% engaged in high-intensity activities. Regarding the form of accompaniment on a visit to a wetland park, 45.5% of visitors indicated that they usually visited a wetland park with friends, followed by family members, accounting for 39.7% of the sample size (Table 4).

4.2. Identifying distinct classes of health perception

Models with increments in the number of classes were estimated to detect a suitable number of latent classes. Multiple statistical indicators were used to determine the best-fit model. The smaller the values of the Akaike information criterion (AIC), Bayesian information criterion (BIC), and adjusted Bayesian information criterion (aBIC), the better the model's fit (47, 57). Entropy evaluates the accuracy of the model classification, and a value closer to 1 indicates a better fit (58). The Lo–Mendell–Rubin

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TABLE 1 Questionnaire scale form.

Latent variable	Code	Measuring question (Indicator)
Physical landscape perception (PLP)	PLP01	The wetland park has a large area of natural and human-made lakes and reservoirs
	PLP02	The wetland park is rich in animal and plant resources
	PLP03	The trees in the wetland park provide shade for pedestrians
	PLP04	The wetland park has enough open space and water-friendly leisure facilities
	PLP05	The wetland park has walkways for people
	PLP06	The wetland park provides a place to breathe fresh air
	PLP07	The wetland park provides a place to soak up the sun
	PLP08	The wetland park provides a place to observe nature and appreciate the beauty
Society landscape perception (SL)	SL01	The wetland park provides a relaxed social environment
	SL02	The wetland park provides a place for face-to-face communication
	SL03	In the wetland park, I can communicate and interact with my peers more actively
	SL04	I like to walk my dog or take my baby to the wetland park
	SL05	It is easier to find like-minded people with similar interests in wetland parks
	SL06	The wetland park promotes the development of restaurants and real estate around it
Symbolic landscape perception (SLP)	SLP01	The wetland park is rich in aquatic plants
	SLP02	Wetland landforms are rich in types
	SLP03	The wetland park can provide freshwater resources, aquatic products
	SLP04	Known as the 'green lung of the city', the park boasts a wide variety of plants
	SLP05	Wetland parks reduce urban carbon emissions
	SLP06	Wetland parks can mitigate runoff, store flood and prevent drought
	SLP07	Wetland parks have open water and are known as the 'kidneys of the Earth'
	SLP08	Wetlands are called 'cradles of species'
Restorative experience (PE)	PE01	In the wetland park, it can solve my mental health problems and psychological distress
	PE02	In the wetland park, I can experience harmony between humans and nature
	PE03	In the wetland park, I can get rid of the dull work pressure and life pressure temporarily
Health perception (HP)	HP01	My health is now excellent
	HP02	I do not think I'm ill
	HP03	I do not think I'm in sub-optimal health at the moment
	HP04	I feel better when I'm in the wetland park than when I'm not
	HP05	In the near future, I expect to have better health than other people I know
	HP06	I will not probably be sick a lot in the future
	HP07	I expect to have a very healthy life
	HP08	In the future, I will probably have fewer health problems than most people around me
	HP09	After visiting the wetland park, my sleep quality improved
	HP10	After visiting the wetland park, my breathing became more relaxed
	HP11	After visiting the wetland park, I had more energy
	HP12	After visiting the wetland park, I became more active
	HP13	After visiting the wetland park, my reflexes became stronger
	HP14	After visiting the wetland park, I look better
	HP15	After visiting the wetland park, my physical pain disappeared or lessened

(Continued)

TABLE 1 (Continued)

Latent variable	Code	Measuring question (Indicator)
Dispositional optimism (DO)	DO01	I always feel optimistic about the future
	DO02	I always thought I was useful
	DO03	I always feel relaxed
	DO04	I'm always willing to make new friends
	DO05	I've always been full of energy
	DO06	I have always been able to solve problems properly
	DO07	I've always been able to think clearly
	DO08	I've always been pleased with myself
	DO09	I've always felt connected to others
	DO10	I've always been confident
	DO11	I've always been able to make my own decisions
	DO12	I feel loved all the time
	DO13	I'm always in a good mood
	DO14	I'm always interested in new things

(LMR) and bootstrapped likelihood ratio test (BLRT) provide a value of p that can be used to compare the increase in model fit between neighboring class models and to determine a statistically significant improvement in fit when another class is included. As shown in Table 5, the AIC, BIC, and aBIC decreased as the number of categories increased. It is possible that the higher the number of categories, the better the fit. However, from Class 3, the entropy started to decrease, and from Class 4, the LMR (P) also started to become statistically insignificant ($p > 0.05$), indicating that the model's fit gradually deteriorated from Class 3. The entropy was closest to 1 in Class 3, which means that the model has the best-fit and classification accuracy. A model with three latent classes was selected as the most appropriate for this study, considering the practical significance of the classes and the fit values p represented by the classes.

Based on the three-class model, Figure 2 illustrates the probabilities of respondents' health perception in each latent class. Latent class 1 (C1) was characterized by high probabilities for all health perception components and labeled 'good self-perception of health' ($n = 323$, 55.5%). Latent class 2 (C2) was characterized by high probabilities of good health status in the present and future but did not improve significantly after the visit to the wetland park and was, therefore, named 'neutral self-perception of health' ($n = 192$, 33.0%). Latent class 3 (C3) was characterized by low probabilities of all health perceptions; accordingly, we labeled it 'poor self-perception of health' ($n = 67$, 11.5%).

4.3. Roles of different factors in predicting class membership

We further conducted a multinomial logistic regression model to examine the respondents' health perceptions associated with their social backgrounds and behavioral activities, with Class 2 (medium self-perception of health) as the reference group (Table 6).

Compared with Class 2, respondents in Class 1 (good self-perception of health) were more likely to be unmarried (OR = 1.24, $p < 0.001$), master and above (OR = 1.25, $p < 0.001$), students or freelancers (OR = 1.22, $p < 0.001$; OR = 1.36, $p < 0.01$), in a group accommodation (OR = 1.22, $p < 0.05$) and under open and semi-closure management of residential areas during the outbreak period (OR = 1.21, $p < 0.05$; OR = 1.21, $p < 0.05$). The main purposes for visiting the park were more likely to be for rest and relaxation (OR = 1.25, $p < 0.01$). The probabilities of visiting the park with friends were high, and weekly park visits before the outbreak were high (OR = 1.21, $p < 0.05$; OR = 1.86, $p < 0.001$).

Compared with Class 2, respondents in Class 3 (poor self-perception of health) were more likely to be female (OR = 1, $p < 0.05$), unmarried (OR = 1, $p < 0.001$), with a higher vocational or junior college degree (OR = 1.07, $p < 0.05$), with a master's degree and above (OR = 2, $p < 0.05$), students (OR = 1, $p < 0.05$), in a group accommodation (OR = 1, $p < 0.05$), and under semi-closure management of residential areas during the outbreak period (OR = 1, $p < 0.01$). Accommodation was more than 5 km away from the wetland park (OR = 1.84, $p < 0.05$). The main purposes of visiting the park were more likely to be for rest and relaxation (OR = 1, $p < 0.001$). The probabilities of visiting the park with friends and visiting the park 6 months before the outbreak (OR = 1.36, $p < 0.05$; OR = 1, $p < 0.05$).

4.4. Structural equation modeling results

Table 7 shows that the critical fitting indices of C1 and C2 are within the acceptable recommended value range; thus, models C1 and C2 have good fitting degrees. The CFI and TLI of C3 are within the acceptable recommended value range, respectively; however, the RMSEA of C3 suggests an insufficient model fit. Overall, the model's fit was considered acceptable, as RMSEA can suggest a below-adequate model fit for models with low degrees

TABLE 2 Background information of respondents ($n = 582$).

Variable	Count	Percentage
Gender		
Men	261	44.8%
Women	321	55.2%
Age (years)		
<18	13	2.2%
18–45	462	79.4%
>45	107	18.4%
Marital status		
Unmarried	367	63.1%
Married	215	36.9%
Education		
High school or less	85	14.6%
Senior or tertiary	54	9.3%
Bachelor's degree	328	56.3%
Master and above	115	19.8%
Work status		
Students	203	34.9%
Unemployed or non-working	19	3.3%
Freelance	79	13.6%
Employed	199	34.2%
Employers	16	2.7%
Other	66	11.3%
Monthly income		
<3,000 CNY	198	34%
3,000–6,000 CNY	149	25.6%
6,000–9,000 CNY	103	17.7%
9,000–12,000 CNY	61	10.5%
12,000–15,000 CNY	35	6%
>15,000 CNY	36	6.2%
Housing		
Dormitory	203	34.9%
Apartment (rented and shared with other tenants)	52	8.9%
Apartment or studio (rented alone)	86	14.8%
Apartment (self-owned)	47	8.1%
Living with families	177	30.4%
Other	17	2.9%
Community management		
Fully locked	76	13.1%
Half-locked	256	44%
Open	250	42.9%
Local residential time		
<1 year	96	16.5%
1–3 years	154	26.5%
3–5 years	78	13.4%
>5 years	254	43.6%

TABLE 3 Traffic-related behavioral factors ($n = 582$).

Variable	Count	Percentage
The distance of most visited urban wetland park from residence		
< 1 km	49	8.4%
1–3 km	120	20.6%
3–5 km	107	18.4%
> 5 km	306	52.6%
Mode of transport		
Walking	79	13.6%
Bicycle or motorbike	64	11%
Public transport or underground	173	29.7%
By taxi or by car	242	41.6%
Other	24	4.1%

TABLE 4 Respondents' behavioral factors ($n = 582$).

Variable	Count	Percentage
Frequency of visit		
Rarely go	77	13.2%
Half a year	274	47.1%
Once every 4–6 months a year	74	12.7%
Once every 2–3 months a year	67	11.5%
Once or twice a month	43	7.4%
Multiple times per month	32	5.5%
Every week	15	2.6%
Purpose		
Sports and fitness	64	11%
Rest and relaxation	405	69.6%
Social events	65	11.2%
Science activities	20	3.4%
Other	28	4.8%
Activity intensity		
Light strength	490	84.2%
Medium intensity	80	13.7%
High strength	12	2.1%
Companionship		
Alone	51	8.8%
Family members	231	39.7%
Friends	265	45.5%
Walking a dog	22	3.8%
Other	13	2.2%

TABLE 5 Estimated indices for comparing different numbers of latent classes.

Class number	AIC	BIC	aBIC	Entropy	LMP	BLRT
1	10261.499	10326.996	10279.376			
2	7069.446	7204.807	7106.393	0.954	0	0
3	6233.476	6438.7	6289.493	0.966	0	0
4	5939.374	6214.462	6014.461	0.931	0	0
5	5865.218	6210.169	5959.374	0.918	0.1261	0.1285

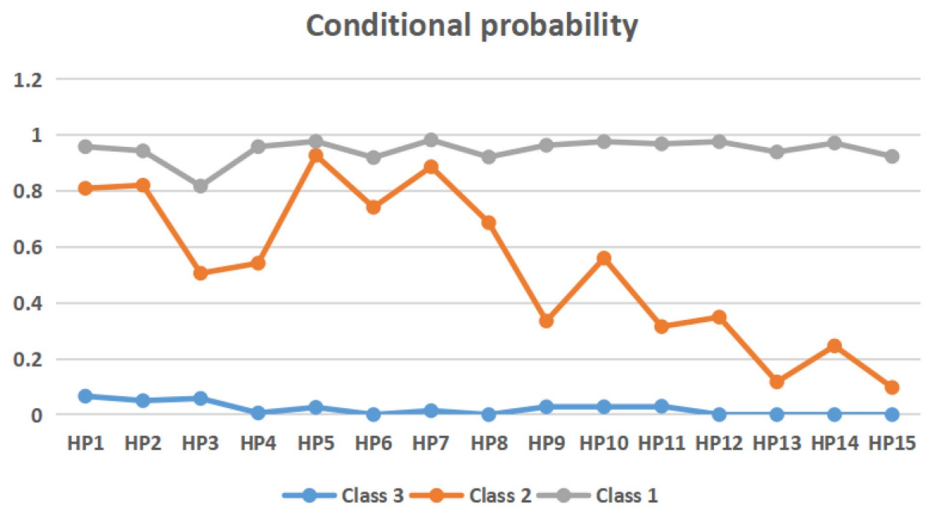

FIGURE 2
Conditional probability of three-class model.

of freedom (59). The relevant structural equation modeling adjustments are detailed in Appendix A.

The research model's hypothesis was validated using AMOS 24.0, and the standardized path coefficients and significance levels between the latent variables are shown in Figure 3. The final hypothesis validation results are shown in Figure 3.

As shown in Tables 8–10, the standardized factor loadings between the latent variables and all the corresponding observed variables are >0.5. Regarding the structural models, Table 11 presents the estimation results for the three latent classes; those for latent class 1 are as follows (Figure 3A). Visitor's physical landscape perception ($\gamma = 0.114$, $p = 0.021$) and social landscape perception ($\gamma = 0.285$, $p < 0.001$) were positively significant on health perception. Visitors' perceptions of the social landscape ($\gamma = 0.191$, $p = 0.005$) and symbolic landscape ($\gamma = 0.350$, $p < 0.001$) were positively significant for their restorative experiences. The effect of visitors' restorative experience ($\gamma = 0.332$, $p<0.001$) and character optimism ($\gamma = 0.378$, $p<0.001$) on health perceptions was positively significant. The relationship between the visitors' symbolic landscape perception variables ($\gamma = 0.039$, $p = 0.526$) and health perceptions was not significant.

The results in C2 were as described below (Figure 3B). In terms of perceived landscape, perceived symbolic landscape ($\gamma = 0.335$, $p = 0.035$) had a positive and significant effect on health perception. Restorative experiences ($\gamma = -0.163$, $p = 0.239$) and health perceptions were not significantly related to each other. Dispositional optimism ($\gamma = 0.353$, $p<0.001$) significantly and positively influenced health perceptions. In terms of restorative experience, the perceived physical landscape ($\gamma = 0.042$, $p = 0.694$) was not significantly related to restorative experience. Perceived social landscape ($\gamma = 0.227$, $p = 0.0.011$) and symbolic landscape ($\gamma = 0.558$, $p < 0.001$) significantly influenced restorative experience.

For latent class 3 (Figure 3C), social landscape perception ($\gamma = 0.405$, $p = 0.015$) influenced health perception, while dispositional optimism ($\gamma = -0.044$, $p = 0.725$) had no significant relationship with health perception.

5. Discussion

We investigated the impact of restorative landscapes in wetland parks on the health perceptions of respondents during the COVID-19 pandemic. By classifying respondents' health perceptions into latent classes, we found that visitors could be classified into three groups with significant group heterogeneity in the population. Sociodemographic characteristics and behavioral factors showed different associations with each group.

Compared with the 'medium self-perception of health' class, respondents in the 'good self-perception of health' group were more likely to be freelancers and have a higher education level. Consistent with previous studies, freelancers have more time at

TABLE 6 Results of multinomial logistic regression.

Independent variable	C1		C3	
	P	OR	*P*	OR
Gender (ref: men)				
Women	0.114	1.21	0.009	1.00
Marital status				
Unmarried	0.001	1.24	0	1.00
Education				
High school or technical secondary school	0.068	1.41	0.157	1.00
Higher vocational or junior college	0.136	1.48	0.022	1.07
Bachelor's degree	0.695	1.21	0.361	1.15
Master and above	0.001	1.25	0.033	2.00
Work status				
Students	0.001	1.22	0.003	1.00
Freelance	0.008	1.36	0.108	1.00
Employed, Employers	0.442	1.22	0.96	1.01
Housing				
Group accommodation	0.015	1.22	0.027	1.00
Rent alone, share house	0.057	1.25	0.986	1.02
Living with family	0.344	1.24	0.071	1.06
Community Management				
Half-locked	0.035	1.21	0.002	1.00
Open	0.035	1.21	0.131	1.04
Distance from residence				
1–3 km	0.734	1.26	0.802	1.00
3–5 km	0.61	1.28	0.617	2.08
>5 km	0.79	1.21	0.028	1.84
Purpose				
Rest and relaxation	0.004	1.25	0	1.00
Social events	0.211	1.37	0.459	1.00
Science activities	0.305	1.85	0.247	1.23
Forms of companionship				
Family members	0.304	1.22	0.106	1.00
Friends	0.02	1.21	0.002	1.36
Walking a dog	0.308	1.70	0.722	1.02
Frequency of park visits before the epidemic				
Half a year	0.768	1.21	0.036	1.00
Once every 4–6 months a year	0.076	1.31	0.607	2.16
Once every 2–3 months a year	0.629	1.36	0.393	1.08
Once or twice a month	0.609	1.45	0.327	1.88
Multiple times per month	0.74	1.60	0.143	1.84
Every week	0	1.86	0.397	2.10

OR, dominance ratio; if the dominance ratio is greater than one, the probability of membership being classified into a particular class increases with each unit of the predictor variable. If the dominance ratio is less than 1, the probability of membership being classified into a particular class decreases for each unit of the predictor variable.

their disposal and fewer stressors than other professionals, and participating in leisure and recreational activities can reduce psychological stress and improve their physical and mental wellbeing. With the improvement in education level, highly educated people have a relatively high preference for wild nature and a strong restorative experience in wetland parks (23). Our

results also showed that residents of unsealed neighborhoods had a higher probability of belonging to the 'good self-perception of health' category during the peak of the epidemic. Lockdown measures have been a panacea for pandemic control. However, home restrictions and the overall disruption of personal daily life have made people exercise less; the workspace in a home office environment has increased the chances of physical pain and other physical health conditions, and blurred work–life boundaries can make it difficult to detach mentally from work, which can increase stress and anxiety. Therefore, when dealing with major safety and health events such as the epidemic, the community and the wetland park should adopt a 'closed' and 'open' relationship (12, 60–64). The frequency and intensity of park cleaning and disinfection can be increased within the park, and infrastructure to stimulate exercise can be incorporated. The maximum number of visitors to a park during an outbreak can also be predicted, and spaces with a large distribution of visitors can be monitored for flow and effective evacuation guidance. Outside the parks, it is necessary to increase connections with residents in neighboring communities and improve residents' accessibility to parks (65).

Compared to the 'medium self-perception of health' group, the 'poor self-perception of health' group was more likely to include women. Consistent with previous studies, gender strongly shapes the experience of visitors to urban parks, with men being more likely than women to rate health benefits when visiting urban blue-green spaces at peak times. In addition, the more frequently residents visit parks, the better their perceived health status, which indicates that park users develop place attachment and increased affinity with nature, which contribute to health benefits. The more residents lived in a wetland park, the worse their perceived health. This is because, at the peak of the epidemic, many non-essential commercial and public spaces were off-limits.

TABLE 7 Structural equation model fit index values.

Accessory indicators	Fit		
	C1	C2	C3
X^2	1715.787	1198.198	26.723
X^2/df	2.186	1.517	1.782
RMSEA	0.061	0.052	0.109
CFI	0.912	0.911	0.971
TLI	0.903	0.903	0.945

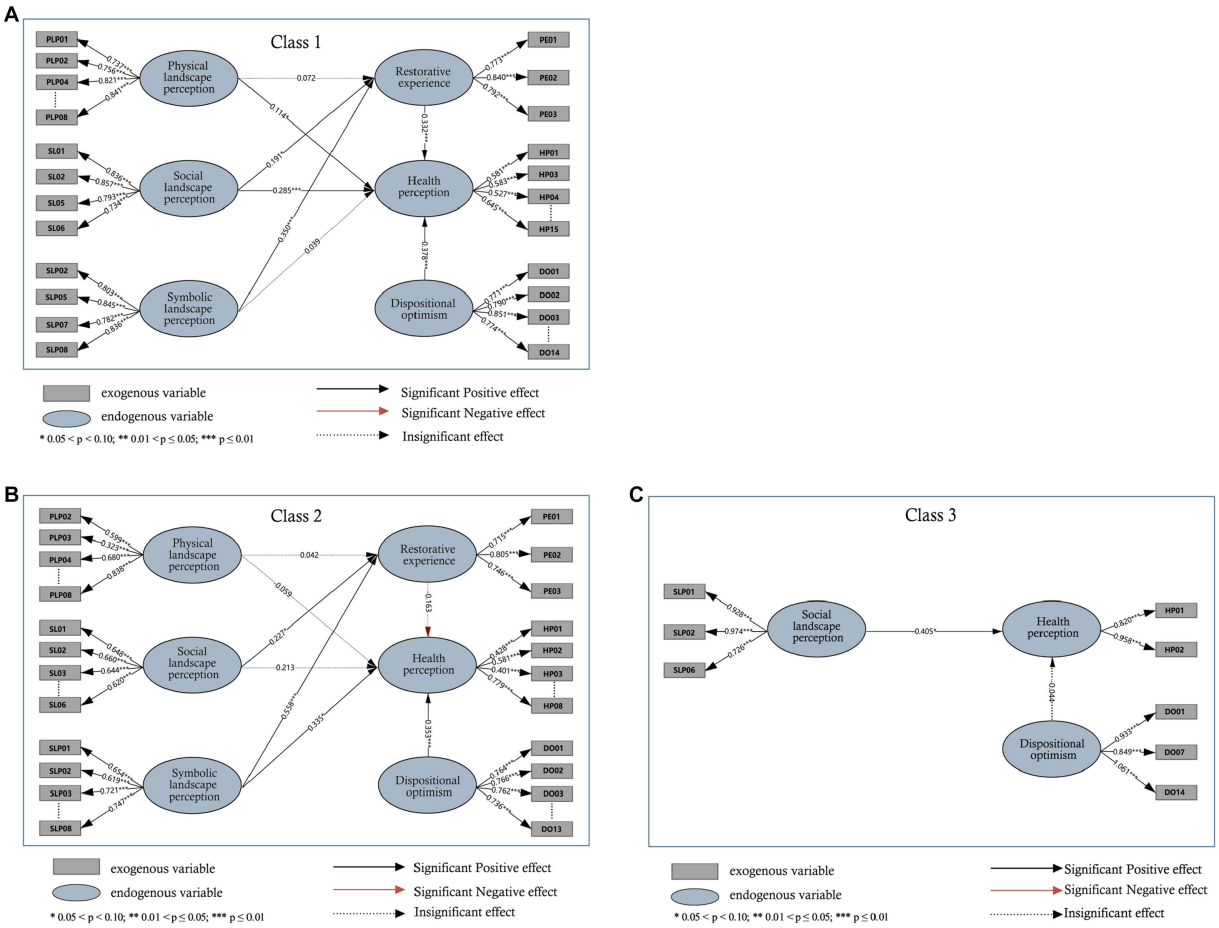

FIGURE 3
SEM estimation results: **(A)** Class 1. **(B)** Class 2. **(C)** Class 3.

TABLE 8 Results of the measurement model of C1.

Variables	Estimate	*p*	Variables	Estimate	*p*
Physical landscape perception			Health Perception		
PLP01	0.737	***	HP01	0.581	***
PLP02	0.756	***	HP03	0.527	***
PLP04	0.821	***	HP04	0.598	***
PLP05	0.860	***	HP08	0.583	***
PLP06	0.908	***	HP09	0.726	***
PLP07	0.845	***	HP10	0.748	***
PLP08	0.841	***	HP11	0.691	***
Social landscape perception			HP12	0.726	***
SL01	0.836	***	HP13	0.666	***
SL02	0.857	***	HP14	0.702	***
SL05	0.793	***	HP15	0.645	***
SL06	0.734	***	Dispositional optimism		
Symbolic landscape perception			DO01	0.771	***
SLP02	0.803	***	DO02	0.790	***
SLP05	0.845	***	DO03	0.851	***
SLP07	0.782	***	DO04	0.806	***
SLP08	0.836	***	DO05	0.851	***
Restorative experience			DO06	0.845	***
PE01	0.773	***	DO07	0.857	***
PE02	0.840	***	DO08	0.914	***
PE03	0.792	***	DO10	0.855	***
			DO11	0.831	***
			DO12	0.781	***
			DO13	0.856	***
			DO14	0.774	***

***$p < 0.01$, **$0.01 \leq p < 0.05$, *$0.01 \leq p < 0.1$.

People's need to visit outdoor spaces was higher than ever. Thus, the closer the urban wetland park was to the neighbourhood, the more people had access to the park, and the more likely they felt healthy. Therefore, it is possible to extend the opening hours of wetland park services during epidemics and improve accessibility to parks while observing more accurate infection prevention methods to ensure wetland park use (65, 66).

The SEM results of the three categories showed that landscape perception, optimistic personality tendencies, and restorative experiences had different strengths and associations with health perception. It is worth noting that in the first category, the symbolic landscape has no positive effect on health perception and restorative experience, possibly because the environmental elements and cultural cues associated with symbolic restorative health in China's wetland parks have not yet established positive images for people. Fewer psychological hints about health are available to visitors compared to those available at famous sites known for longevity and healing. Therefore, in future construction of wetland parks, planning designers can try to add cultural clues and symbols with symbolic significance for health and create environmental factors conducive to the healthy restoration of wetland parks. Additionally, the results showed that optimism had an impact on health perceptions regardless of group, and optimists' positive expectations are not limited to specific areas of behavior or types of circumstances.

6. Conclusion

This study examined the impact of wetland park landscapes on different health-perceiving populations during the COVID-19 pandemic. The study identified various factors affecting the potential categories of health perception of visitors, such as gender, marital status, education, work status, housing, community management, distance from home, purpose, form of companionship, and frequency of pre-pandemic park visits. The existence of different pathways and correspondence coefficients among the three potential categories of visitor groups was also investigated. In the event of a future major safety and health event, wetland park managers should pre-emptively address the need for 'closed' and 'open' relationships between communities and wetland parks and try to increase cultural cues and symbols with

TABLE 9 Results of the measurement model of C2.

Variables	Estimate	*p*	Variables	Estimate	*p*
Physical landscape perception			Restorative experience		
PLP02	0.599	***	PE01	0.715	***
PLP03	0.623	***	PE02	0.805	***
PLP04	0.680	***	PE03	0.746	***
PLP05	0.831	***	Health perception		
PLP06	0.811	***	HP02	0.581	***
PLP07	0.756	***	HP03	0.401	***
PLP08	0.838	***	HP06	0.675	***
Social landscape perception			HP07	0.543	***
SL01	0.648	***	HP08	0.779	***
SL02	0.660	***	Dispositional optimism		
SL03	0.644	***	DO01	0.764	***
SL04	0.668	***	DO02	0.766	***
SL05	0.737	***	DO03	0.762	***
SL06	0.620	***	DO04	0.749	***
Symbolic landscape perception			DO05	0.794	***
SLP01	0.654	***	DO06	0.839	***
SLP02	0.619	***	DO07	0.789	***
SLP03	0.721	***	DO08	0.771	***
SLP04	0.686	***	DO09	0.752	***
SLP05	0.664	***	DO10	0.850	***
SLP06	0.776	***	DO11	0.669	***
SLP07	0.757	***	DO13	0.736	***
SLP08	0.747	***			

***$p < 0.01$, ** $0.01 \leq p < 0.05$, *$0.01 \leq p < 0.1$.

TABLE 10 C3: Results of the measurement model.

Variables	Estimate	*p*
Social landscape perception		
SL01	0.928	***
SL02	0.974	***
SL06	0.726	***
Health perception		
HP01	0.820	***
HP02	0.958	***
Dispositional optimism		
DO01	0.933	***
DO07	0.849	***
DO14	1.061	***

health symbolism. However, this study had several limitations. First, the findings were limited to Chinese participants. Future studies should explore cross-cultural comparisons among visitors from different countries. Second, this study did not examine the dynamics of health perceptions over time. Future research could examine longitudinal changes in the health perceptions of wetland parks. These insights can inform the decision-making process and contribute to better planning and management of wetland parks.

TABLE 11 Results of the structural model.

hypothesis	C1			C2			C3		
	Estimate	*p*-Value	Conclusion	Estimate	*p*-Value	Conclusion	Estimate	*p*-Value	Conclusion
H1a	0.114	0.021	Support	−0.059	0.636	Not supported	\	\	\
H1b	0.285	***	Support	0.213	0.067	Not supported	0.405	0.015	Support
H1c	0.039	0.526	Not supported	0.335	0.035	Support	\	\	\
H2a	0.124	0.072	Not supported	0.042	0.694	Not supported	\	\	\
H2b	0.191	0.005	Support	0.227	0.011	Support	\	\	\
H2c	0.350	***	Support	0.558	***	Support	\	\	\
H3	0.332	***	Support	−0.163	0.239	Not supported	\	\	\
H4	0.378	***	Support	0.353	***	Support	−0.044	0.725	Not supported

*** indicates $p < 0.001$, ** indicates $p < 0.01$, * indicates $p < 0.05$.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

JL: Conceptualization, Funding acquisition, Resources, Supervision, Writing – original draft. YC: Writing – original draft, Data curation, Formal analysis, Investigation, Methodology. XC: Conceptualization, Funding acquisition, Resources, Writing – review & editing. SL: Funding acquisition, Resources, Supervision, Writing – review & editing. YP: Conceptualization, Methodology, Writing – review & editing. TF: Writing – review & editing. JQ: Formal analysis, Investigation, Writing – original draft. YJ: Formal analysis, Investigation, Writing – original draft. YX: Formal analysis, Investigation, Writing – original draft. WL: Resources, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix A

Number	Step
1	Model construction: constructing a hypothetical model based on theory requires making assumptions about the relationship between observed variables and latent variables, the interrelationships between each latent variable, etc.
2	Model fitting: The main purpose is to use the sample to estimate the model parameters and to find the set of parameters that minimize the "gap" between the implied covariance matrix of the model and the sample covariance matrix.
3	Model evaluation: significance of path coefficients, reasonableness of the relationship of each parameter to the pre-determined model, passing of each fitting index.
4	Model correction: When the evaluation indicators are not satisfactory, the model is corrected, either by model expansion (using correction indices) or by model restriction (using critical ratios).
	MI amendment: Use the modification index to make corrections to the model.
	Reduction of measurement indicators:Remove terms that do not make sense to ensure that the final measurement model is good. Specifically, exploratory factor analysis was conducted upfront, followed by the use of validation factor analysis, and structural equation modeling was carried out after the measurement relationship was indeed fine, to reduce the interference that a 'bad measurement relationship' would bring to the model.
	Path reduction: Combining explicit and tacit knowledge from the domain and context, impact pathways that did not reach the significance level were removed,
5	modeling summary

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Exploring the potential impact of group identity on post-traumatic growth in the aftermath of Corona outbreak: function of social–emotional competence as a mediator

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Background: This research endeavors to examine the potential effects of human and societal interactions on individuals' post-traumatic growth in the aftermath of the Corona outbreak. To achieve the aforementioned objective, the current research investigates the correlations between post-traumatic growth and group identity, while also examining the potential mediating function of social–emotional competence.

Methods: A cross-sectional design included a representative sample of 2,637 high school students located in the capital territory of Pakistan using convenience sampling method. To explore the associations, correlation and mediation analyzes utilizing the group identification scale, the social–emotional competence scale, and the post-traumatic growth scale was performed with SPSS PROCESS 4 macro and AMOS.

Results: The findings demonstrated that group identification emerged as a substantial predictor substantially associated with post-traumatic growth. Moreover, the relationship linking group identification and post-traumatic growth was found to be partially moderated by social–emotional competence.

Conclusion: The phenomenon of group identification can exert influence on post-traumatic growth through both direct and mediating pathways, with the latter being essentially mediated by social–emotional competence. The aforementioned outcomes possess significant academic and practical implications concerning the promotion of post-traumatic growth and the improvement of psychological well-being after the Corona outbreak.

KEYWORDS

COVID-19, social–emotional competence, mental wellbeing, human-society relationship, post-traumatic growth

Introduction

There have been multiple scholarly investigations indicating that the ongoing Corona outbreak has posed significant adverse consequences on individuals' psychological well-being, eliciting various psychological symptoms such as anxiety, depression, and post-traumatic stress disorder (PTSD) (1, 2). This impact has been especially pronounced among adolescents and college students, who have faced a range of challenges including but not limited to heightened levels of depression, anger, and sleep-related issues (3). Considering the potential enduring psychological influence of the pandemic, it is of utmost importance to investigate strategies aimed at assisting the general populace in effectively managing the psychological ramifications of Corona outbreak, while also fostering post-traumatic growth in the era following the pandemic. Post-traumatic growth elucidates the salient psychological transformations that may transpire within an individual when confronted with adversity or comparable challenges (4). Notably, these transformative changes encompass an enhanced sense of gratitude toward life, heightened levels of personal fortitude and self-perception, augmented interpersonal connections, and more profound personal encounters (5). A comprehensive examination of existing scholarly works has revealed that post-traumatic growth is closely tied to individuals' psychological emotions, rumination, coping mechanisms, and behaviors (6). Furthermore, numerous research investigations have consistently demonstrated that PTG experienced amidst the corona outbreak is significantly connected to individuals' expectations of life, sense of societal and collective ties, and overall mental well-being (7, 8).

Several aspects exert a substantial impact on an individual's post-traumatic growth, encompassing both intrinsic aspects as well as extrinsic aspects (9–12). Furthermore, it is widely acknowledged that group identity has a pivotal part in influencing people's post-traumatic growth (13). Group identity is a psychological notion that signifies the identification and emotional ties people develop toward a specific community ((14)). This attachment and identification are contingent upon the presence of common traits or circumstances. Ultimately, this process fosters a greater feeling of being related within the community. Limited empirical research has thus far delved into the correlation between group identity and post-traumatic growth. Nevertheless, extant scholarship has demonstrated a robust connection between these two constructs. An empirical investigation indicated that conventional cognitive frameworks acted as obstacles in establishing an effective link with the collective, thereby culminating in adverse affective states that obstructed post-traumatic growth (15). Henson and colleagues discovered that the presence of attachment avoidance within a certain group of academic instructors and students impeded their ability to experience post-traumatic growth (16).

There has been a noticeable increase in scholarly attention toward the significance of social–emotional competence in the regulation of behavioral and cognitive processing (17). Social–emotional competence is conceptualized as an individual's capacity to cognitively recognize and effectively communicate emotions, while also possessing the capacity to comprehend and adeptly utilize emotions across a diverse range of circumstances. Additionally, there exists a robust association between the perception of emotion, logical thinking, and the regulation of emotion (18). Social–emotional competence serves as a crucial contributing factor in facilitating the process of post-traumatic growth. In the realm of scholarly research, investigations were conducted to analyze the emotional competence exhibited by adolescents affected by the global pandemic, coronavirus epidemic, both while in isolation and after its conclusion (19). The findings of these studies substantiate the assertion that heightened social–emotional competence can contribute positively to the process of post-traumatic growth among adolescents. Moreover, multiple studies have demonstrated a positive correlation between self-esteem and general intelligence (20, 21). An illustration of this phenomenon can be observed through research findings revealing that a robust gastrointestinal system is correlated with an elevated state of contentment, subsequently augmenting individual self-esteem and confidence. The literature lacks sufficient exploration of the mediating function of social–emotional competence in the connection between these factors, despite their inherent interconnectedness. Hence, following the advent of the coronavirus outbreak, it becomes imperative to explore how human-society interactions can support individuals in managing the psychological distress caused by Corona disease and foster the development of post-traumatic growth.

To achieve this objective, a comprehensive survey was administered to ascertain the perspectives of secondary education students who have been affected by the Corona outbreak. The primary goal of this investigation was to explore the interconnections between post-traumatic growth and group identity, while simultaneously examining the potential mediating influence of social–emotional competence. The present study offers significant findings about the mental well-being of adolescents, thus facilitating the development of specific psychological interventions to aid individuals impacted by the pandemic.

By conducting a comprehensive evaluation of the available research regarding group identity and post-traumatic growth, a prospective connection between these two constructs has been recognized. These psychological improvements may then contribute to the development of effective coping strategies for people dealing with traumatic events and stressors. According to research, it has been suggested that fostering community engagement and encouraging people to engage in collective engagements and maintain connections with their societal networks amid the Corona outbreak can serve as a facilitator for the cultivation of prosocial behaviors and augmentation of mental wellness (22). Emerging research has proposed that intervention efforts targeting the relationship between adolescents and their interpersonal connections have the potential to mitigate trauma and foster post-traumatic growth, especially in those individuals impacted by the unprecedented Coronavirus global health crisis. Building upon these findings, our hypothesis posits a positive correlation between post-traumatic growth and group identity, i.e., "*H1*: *Group identity has a positive association with post-traumatic growth*".

On the contrary, extant scholarship suggests that social–emotional competence confers significant advantages upon individuals, affording them the capacity to effectively acclimate to both the educational environment and societal context. Additionally, social–emotional competence fosters improved educational achievement, the cultivation of essential adaptive competencies, and the promotion of favorable behavioral and cognitive (23, 24). An empirical investigation conducted in Poland examined the impact of corona epidemic on psychological wellness. The findings indicated the presence of a favorable association between individuals' social–emotional

competence and their mental well-being. Specifically, individuals with elevated social–emotional competence were found to exhibit comparatively low degrees of negative emotional states, including anxiety, sadness, and fear (25). A subsequent investigation not only revealed the potential impact of social support and environmental modifications on students' self-efficacy beliefs but also emphasized their role in moderating such beliefs. The group identity construct presents itself as an additional influential element that has the potential to significantly affect social–emotional competence (26). Research in the literature indicates that social–emotional competence has demonstrable effects on relationships, social interactions, and group identity among adolescents. However, there is widespread consensus that group identity plays a pivotal role in shaping adolescent social–emotional competence (27, 28). The social cognitive notion posits that people engage in the construction of social connections, which subsequently impact their cognitive and interpersonal conduct. Key convictions, including feelings of worth, belongingness, and self-efficacy, are believed to have a significant impact on the evolvement of social–emotional competence. Consequently, the influence of group identity on these perceptions may either facilitate or impede the process of constructing individual social–emotional competence. In light of the aforementioned observations, it is hypothesized that a direct and favorable association exists between group identity and social–emotional competence, i.e., *"H2: group identity has a positive association with social–emotional competence"*.

The Corona outbreak has engendered a growing amount of scholarly research that explores the correlation between social–emotional competence and psychological wellness (29). A research study determined that children possessing elevated levels of social–emotional competence demonstrated less occurrence of cognitive and behavioral difficulties (30, 31). Correspondingly, additional evidence emerged affirming that heightened social–emotional competence aids individuals in enhancing their self-efficacy, job satisfaction, and psychological wellness. According to the emotional intelligence theory, people's level of intellectuality can potentially be manifested through their proficiency in four crucial domains, specifically the discernment of emotions, comprehension of emotions, articulation of emotions, and management of emotions. This paper aims to elucidate the moderating impact of social–emotional competence on human psychology (18). Based on a thorough examination of the existing scholarly literature, it is our assertion that a growth mindset significantly impacts post-traumatic growth. Furthermore, we have discovered a noteworthy significant connection between post-traumatic growth, group identity, and social–emotional competence, and. Based on the aforementioned foundation, we put forward the proposition that: *"H3: Social–emotional competence has a mediation effect on post-traumatic growth and growth identity"*.

Materials and methods

Participants and procedures

This research focused on a cohort of freshmen, specifically those who had been affected by the coronavirus outbreak. The students were selected from the capital territory of Pakistan and fell within the age range of 16 to 18. A sample comprising 2,987 students was chosen as the subjects for the study using the convenience sampling method. Questionnaires in paper format were dispensed to the designated respondents during the period spanning from March to June 2022, after the Corona outbreak. Before commencing with the administration of the questionnaire, the researcher elucidated the purpose and specifics of the research and survey questions to the students partaking in the research. The questionnaires were disseminated after obtaining consent from the parents, classroom teachers, and students, who were subsequently given instructions to complete them. Subsequently, the questionnaires were duly gathered and the acquired data was subsequently inputted. Following the conclusion of data collection, the researcher proceeded to assess the questionnaire's validity. Subsequently, 2,637 questionnaires were deemed valid, after eliminating those with irregular or missing responses. This resulted in a commendable recovery rate of 88.28%.

Materials

The questionnaire used in this investigation consisted of four distinct categories, namely: a social-demographic information tool, a scale measuring group identity, a scale assessing post-traumatic growth, and a scale gaging self-efficacy and coping. The demographic information questionnaire solicited data regarding the respondents' sex, place of residence (PoR), and SES.

Group identity scale

The present investigation utilized the Group Differences in Industrial Organizations (GDIO) scale constructed by Brown et al. (32) to evaluate the extent of group identification. In order to guarantee excellence and reliability, the conclusive questionnaire was comprised of a set of five items. In this metric, individuals are presented with a series of five inquiries designed to evaluate the intensity of their collective affiliation with their peer associations and educational cohorts. Every question on the survey received a positive score on a 5-point Likert scale, except one, which received a negative score. The internal consistency reliability of the measure, as measured by Cronbach's alpha coefficient, was moderately high at 0.89 (Table 1).

Social–emotional competence scale

This scale has been widely used to assess social–emotional competence and consists of 12 items, divided into four distinct categories (33). The questionnaire is rated on a 7-point Likert scale with higher values exhibiting intense levels of pro-social behavior among students. The internal consistency reliability of the measure, as measured by Cronbach's alpha coefficient, was moderately high at 0.88 (Table 1).

TABLE 1 Reliability analysis.

Constructs	Cronbach's α
Group identity	0.89
Post-traumatic growth	0.82
Social emotional competence	0.88

Post-traumatic growth scale

This indicator was derived from the initial scale devised by Cann et al. (34) The adaptation of the scale was necessitated by the variances in cultural contexts and the cognitive maturation of adolescent populations. The questionnaire in its ultimate iteration consisted of four distinct dimensions. The survey consisted of a total of eight inquiries, wherein the respondents' responses were evaluated using a 6-point Likert scale. Higher scores on this scale were indicative of higher levels of post-traumatic growth reported by the participants. The internal consistency reliability of the measure, as measured by Cronbach's alpha coefficient, was moderately high at 0.82 (Table 1).

Covariates

In accordance with existing empirical investigations highlighting the potential correlation between an individual's gender, PoR, and social–emotional competence with post-traumatic growth, we incorporated these factors as covariates within our research framework.

Analytical approach

Data analysis for the present investigation was done using AMOS and the SPSS (v25). Harman's single-factor test procedure was initially employed to assess for common method bias to ensure the quality of the analyzes (35) (36). Pearson correlation analysis and descriptive statistics were also assessed for the selected study participants to ensure normality and no multicollinearity in the data. Then, AMOS was utilized to develop the structural equation model (SEM) and ensure the accuracy of the measurement model. The research hypotheses were tested using the SPSS PROCESS 4 macro. Furthermore, we conducted a rigorous assessment of the hypothesized model using the bootstrapping technique (involving $N = 10{,}000$). Group identification was considered as the explanatory variable, while post-traumatic growth served as the response variable. Social–emotional competence was identified as the mediator, and sex, PoR, and SES were accounted for as covariates.

Results

The survey-based approach could potentially result in common method bias, hence before conducting data analysis, Harman's one-way test was used to examine all items in the questionnaire. The findings indicated the presence of 12 factors with eigenvalues surpassing the value of one. The percentage of maximum factor variance explained was only 19.34%, which is significantly lower than the standard threshold. This suggests that there was no notable common method bias present.

Table 2 shows the basic descriptive attributes of the study participants whereas Table 3 illustrates the Pearson's correlations among the participants. Among the 2,637 participants included in this study, a majority of 1747 individuals (66.25%) identified as females, while 890 individuals (33.75%) identified as males. Regarding the individuals' PoR, 1789 individuals (constituting 67.84%) were situated in urban areas, while 848 individuals (accounting for 32.16%) resided in rural locations. Further, we examined the potential connections between participants' sex, PoR, and SES with social–emotional competence and post-traumatic growth by assessing the connections between these factors and the key factors. The findings indicated that only sex and PoR had a connection with SES, whereas SES was significantly linked to group identity, social–emotional competence, and post-traumatic growth. In the meantime, there was a substantial and positive correlation between post-traumatic growth, group identity, and social–emotional competence, and. In addition, the

TABLE 2 Descriptive analysis.

			$\bar{X} \pm SD$	Significance	Effect size
Group identity			21.68 ± 4.95		
	Sex			0.04	0.10
		Male	21.42 ± 5.11		
		Female	22.39 ± 4.23		
	PoR			<0.01	0.25
		Urban	24.14 ± 4.84		
		Rural	24.05 ± 4.26		
Post-traumatic growth			77.11 ± 12.45		0.40
	Sex			<0.01	
		Male	76.85 ± 14.05		
		Female	75.43 ± 12.05		
	PoR			<0.01	
		Urban	77.45 ± 11.24		
		Rural	71.18 ± 9.51		
Social–emotional competence			61.52 ± 9.53		0.40
	Sex			0.03	
		Male	60.44 ± 9.74		
		Female	61.85 ± 8.88		
	PoR			0.02	
		Urban	61.72 ± 9.15		
		Rural	60.21 ± 9.76		

PoR, place of residence, $\bar{X}$, mean, SD, standard deviation, significance level $p < 0.05$.

TABLE 3 Pearson's correlation analysis.

	Sex	PoR	SES	GI	SEC	PTG
Sex	1					
PoR	−0.234*	1				
SES	0.347**	−0.205*	1			
GI	0.149	−0.146	0.217*	1		
SEC	0.258**	−0.284**	0.339	0.469**	1	
PTG	−0.373	−0.147	0.262*	0.437**	0.512**	1

*$p < 0.05$, **$p < 0.01$, PTG, post-traumatic growth; SEC, social–emotional competence; GI, group identity; PoR, place of residence; SES, socioeconomic status.

results of Pearson correlation coefficients confirmed the absence of multicollinearity among study variables as no coefficient exceeded 0.7.

We employed AMOS to conduct a confirmatory factor analysis and assess the validity of our primary constructs. The simple mediator model that was proposed resulted in appropriate model adequacy. The confirmatory factor analysis study indicated that the measurement model was suitable, with acceptable fit indices: RMSEA = 0.031, SRMR = 0.030, CFI = 0.96, and TLI = 0.97. In the context of analyzing a simple mediation model with explicit variables, the utilization of SPSS PROCESS proves to be an uncomplicated and efficient approach (Table 4). It is considered more appropriate for conducting mediation analyzes with variables of an explicit nature as compared to AMOS.

Furthermore, an analysis employing the SPSS PROCESS tool (model 4) was employed to undertake multiple regression analysis, wherein group identity served as the explanatory variable, post-traumatic growth as the response variable, and social–emotional competence as the mediating factor. As hypothesized, the group identity demonstrated a statistically significant positive predictive influence on post-traumatic growth ($\beta = .328$, $p < 0.01$) Furthermore, it was observed that there was a substantial and affirmative correlation between group identity and social–emotional competence ($\beta = .374$, $p < 0.01$). This significant positive correlation further extends to the relationship between social–emotional competence and post-traumatic growth ($\beta = .458$, $p < 0.01$; Table 5).

Furthermore, the bootstrap method was employed to identify and assess the presence of mediating impacts. After controlling for confounding factors, i.e., sex, PoR, and SES variables, the 95% confidence interval for the mediating effect of group identity on post-traumatic growth through SES and social–emotional competence was observed to be (0.032–0.113). Similarly, the 95% confidence interval for the direct impact of group identity on post-traumatic growth was determined to be (0.101–0.223). Importantly, neither of these intervals contained the value 0, suggesting a statistically significant relationship between these variables (Table 6). It is evident from the outcomes that group identity can have an indirect impact on post-traumatic growth through social–emotional competence. Additionally, group identity also exerts a direct influence on post-traumatic growth, whereby the direct effect constitutes 70.88% of the overall effect, while the mediating effect corresponds to 29.12%. Overall, the research outcomes indicate a significant and positive correlation between the growth mindset of freshmen and their post-traumatic growth. This relationship is mediated by students' socioeconomic status, thus providing support for the formulated hypotheses.

TABLE 4 Model fit indices.

Indices	Values
χ^2 / *df*	1.37 ($p < 0.001$)
RMSEA	0.031
SRMR	0.030
CFI	0.96
TLI	0.97
IFI	0.96

RMSEA, root mean square error of approximation; SRMR, standardized root means square residual; CFI, comparative fit index; TLI, Tucker-Lewis's index; IFI, incremental fit index.

Discussion

This study aims to investigate the underlying mechanism between post-traumatic growth and group identity, while also considering the mediating function of social–emotional competence in the aforementioned associations. The population consists of Pakistani adolescents who have encountered the effects of the Corona outbreak. The study outcomes indicate that group identity factors have a constructive impact on post-traumatic growth. Additionally, it was observed that social–emotional competence plays a significant mediating role in the relationship between post-traumatic growth and group identity. The present findings affirm our initial hypotheses and contribute additional insight to the existing body of research by

TABLE 5 Regression analysis.

	PTG (R^2 =0.129)			SEC (R^2 =0.348)			PTG (R^2 =0.217)		
	β	*t*	Sig.	β	*t*	Sig.	β	*t*	Sig.
GI	0.328	9.26**	<0.01	0.374	12.35**	<0.01	0.219**	8.36	<0.01
SEC							0.458	14.68	<0.01
Sex				0.163	7.25*	0.03	−0.127	−3.58	0.347
PoR				−0.196	−8.729**	<0.01	−0.078	−2.61	0.762
SES				0.203	6.77**	<0.01	0.113	5.65	0.943
F-statistics	19.50**			24.49**			29.16**		

*$p < 0.05$, **$p < 0.01$, PTG, post-traumatic growth; SEC, social–emotional competence; GI, group identity; PoR, place of residence; β, regression coefficient; SES, socioeconomic status.

TABLE 6 Bootstrapping analysis of effect size.

	Effect estimate	Bootstrapped SE	Bootstrapped (95% CI)	Ratio
Direct effect	0.129	0.019	0.101–0.223	70.88%
Mediating effect	0.053	0.011	0.032–0.113	29.12%
Composite effect	0.182	0.021	0.163–0.315	

SE, standard error; CI, confidence interval; significance level at $p < 0.05$.

providing a deeper understanding of the correlation between post-traumatic growth and group identity.

The present investigation has elucidated a notable correlation between post-traumatic growth and group identity. This finding aligns with prior empirical investigations that have subsequently substantiated that individuals possessing high levels of group identity tend to also exhibit substantial psychological resilience and optimal mental well-being (37) (38). In our research, we have conducted a comparative analysis of previous studies conducted by different researchers revealing a confluence of findings (10) (39) (40). This confluence provides empirical evidence supporting the proposition that the social identity notion can be utilized as a comprehensive approach for exploring and elucidating the relationship between group identity and post-traumatic growth. The notion addresses this by elucidating the mechanism by which people establish affiliations with societal collectives, elucidating how group identity can function as the foundation for people's self-esteem, and equipping people with tactics to effectively address and surmount adversities in their personal experiences ((41)). The implementation of these approaches can aid people in effectively managing and coping with adversities (38). Irrespective of a person's affiliation, enhancing one's group identity or people's ability to effectively manage and overcome challenges can prove to be a pivotal determinant. Enhancing one's sense of belonging and self-worth via elevated group identity or a robust affiliation with any collective can effectively promote both psychological and physical well-being, thereby effectively perpetuating a condition of sound mental health (42) (43). It has been discovered that initiatives targeting the enhancement of group identity have demonstrated a capacity to mitigate the detrimental effects of loneliness stemming from the coronavirus outbreak (44). Moreover, such interventions have exhibited an ability to ameliorate individuals' sense of belonging and self-worth, while concurrently fostering psychological well-being (45). Moreover, individuals who cultivate a sense of group identity through the utilization of social media platforms amidst the Corona outbreak have conveyed a marked decrease in feelings of isolation and psychological anguish. Furthermore, a strong level of group identity is indicative of lower levels of mental disorders. According to evidence in the field of clinical medicine, it has been found that various factors, such as social support, social inclusion, interventions aimed at improving social relationships, as well as tailored psychological interventions, have the potential to attenuate mental distress and facilitate post-traumatic growth in individuals who have undergone traumatic experiences, such as hospitalization due to Coronavirus (46, 12). These outcomes substantiate the significance of perceived growth and the enhancement of positive mental changes among people.

The results of our investigation add to prior studies on group identity and post-traumatic growth by showing that group identity is a significant determinant of social–emotional competence, supporting earlier conclusions that people who have elevated group identity are likely to have higher social–emotional competence (47, 48). Recent studies have indicated that group identity likely strengthens societal bonding and enhances interactions between individuals (49). For example, Willems and his colleagues discovered that people who have a high level of self-disclosure tend to have strong interconnection, which contributes to their ability to establish and sustain positive connections with others (50). Additionally, a study has revealed that students who form relatively vigorous societal ties tend to gain more social–emotional and cognitive learning through social interaction, resulting in higher levels of social–emotional competence (21, 51). Our research supports the social cognitive notion, which suggests that people form social relationships to shape their emotional and social actions based on their interpretations (52). Thus, perceptions play a significant role in shaping social–emotional competence. According to a study on the Corona outbreak, *Ntontis* discovered that there is a strong connection between group identity, social support, and resilience, with perceived stress showing a negative correlation (53). This suggests that both group identity and social support can influence how individuals perceive things, enabling them to manage their mental well-being, reduce psychological pressure, and ultimately improve their overall socio-economic condition (54, 55). Receiving assistance from one's social circle including family, friends, and community during stressful situations like the coronavirus outbreak can help individuals feel connected and valued, ultimately enhancing their sense of belonging and self-esteem, while also boosting psychological well-being (56, 57). Hence, strengthening general intelligence is likely vital for enhancing socioemotional competence in individuals.

In addition, our research uncovered a connection that is favorably correlated between SEC and post-traumatic growth. An empirical investigation conducted among adolescents discovered that individuals with high social–emotional competence are more likely to possess a strong ability to cope with challenges and have an optimistic mindset toward difficult situations (58, 59). This reinforces the idea that social–emotional competence plays a significant role in regulating an individual's mental well-being, as suggested by the emotional intelligence theory. A study showed that people with higher social–emotional competence were better at managing their mental state and emotions during the Crona crisis, allowing them to deal with obstacles constructively (60, 61). Furthermore, people who possess a high socioeconomic status often utilize multiple methods to manage their emotions, cognitive and coping mechanisms (19, 62). They may face challenging circumstances and approach life with positivity by putting constructive strategies into practice. This enables them to discover new options and build a greater knowledge of their value as individuals, ultimately resulting in post-traumatic growth.

In the aftermath of the Corona outbreak, a considerable number of individuals are confronted with substantial psychological distress and trauma. This research establishes a novel connection between group identity, social–emotional competence, and post-traumatic growth, showcasing its significant implications in both theory and practice. This study initially investigates the underlying mechanism between growth from group identity and post-traumatic growth, utilizing the interplay between individuals and the collective as well as individuals and society. This exploration enhances the understanding of post-traumatic growth's formation mechanism in the aftermath of the Corona outbreak, offering a novel perspective for prospective research endeavors.

Furthermore, our work contributes to the existing body of literature on social–emotional competence and its positive impact on the overall well-being of adolescents. By enhancing their social–emotional competence, adolescents can develop greater

comprehension of others' psychological demands and effectively navigate their own traumatic experiences. These findings also lend support to social identity theory and emotional intelligence theory, thereby reinforcing and expanding their foundational principles. The present work represents a pioneering endeavor in examining the correlation among the above three factors, thereby offering novel insights into comprehending the intricacies and dynamics of posttraumatic growth.

The present study yields several practical significances. To begin with, it is imperative to acknowledge the crucial relationship between group identity and post-traumatic growth. Consequently, it becomes essential to closely monitor the evolution of group identity among adolescents within the wider societal context. Moreover, recognizing the significance of nurturing adolescents' affiliations with various groups and society at large is paramount, as it aids them in surmounting the lasting repercussions caused by events such as the Corona outbreak or other catastrophic occurrences. As an illustration, the creation of strong societal connections and collective affiliations can aid individuals in alleviating the psychological implications, distress, and tension caused by epidemics and disasters. Furthermore, an effective method to augment the social–emotional competence of adolescents, enabling them to effectively manage traumatic events and distress while fostering their post-traumatic growth, involves the integration of social–emotional education within the curriculum. In the pursuit of fostering individual post-traumatic growth, the incorporation of social–emotional education within the daily curriculum serves as a notable approach. This pedagogical strategy endeavors to encourage students to actively comprehend, articulate, and absorb knowledge, thereby facilitating their ability to navigate personal and social relationships. Notably, this educational initiative assumes a pivotal role in advancing post-traumatic growth after the Corona outbreak. This study offers new insights into the post-traumatic growth process and its mechanisms, consequently enriching and enhancing existing knowledge. Moreover, such findings have practical implications for the field of psychotherapy and counseling, enabling therapists to acquire a comprehensive comprehension of their patients' requirements and effectively address them.

Limitations and future directions

The findings of our inquiry necessitate careful consideration of several inherent limitations to appropriately interpret them. The potential introduction of bias in establishing the causality between adolescent group identity, social–emotional competence, and post-traumatic growth could arise due to the cross-sectional nature of the current investigation. In conducting future investigations, it is recommended that researchers employ methodologies such as experimental or longitudinal investigations. These approaches allow for the repeated measurement of adolescents' behavioral functions and shift over an extended duration. By utilizing these methods, researchers can capture a more thorough and profound understanding as well as draw more conclusive findings. Additionally, it is worth noting that the choice of sample process may exhibit a degree of bias, predominantly stemming from the fact that the questionnaires employed typically target exclusively those adolescents who are accessible within the confines of the capital city of Pakistan. Subsequent investigations can enhance the size of their adolescent samples through the deliberate inclusion of participants sourced from various domains such as family members, educational institutions, communal settings, or diverse geographical regions within Pakistan. This intentional broadening of sample selection aims to mitigate the potential bias inherent in the sampling process. Ultimately, the generalizability of the results may be constrained by the fact that the data originated specifically from a subset of Pakistani high school-aged adolescents. Further research is warranted to ascertain the veracity of these findings among diverse populations, thereby ensuring their applicability and generalizability.

Conclusion

The objective of this research was to investigate the correlation between group identity and post-traumatic growth after the Corona outbreak, focusing on the interconnections between humans and society. The results suggest that group identity has a direct impact on post-traumatic growth and also indirectly influences it through social–emotional competence. The outcomes of the present investigation offer additional proof of the growth and intensification of the framework and connection between group identity and post-traumatic growth. They also demonstrate how the dynamics of individuals and groups, as well as people and society, impact people's personal growth and transformation. Smart insights can shape the improvement of public psychological well-being in the era following the Corona outbreak.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by this study was approved by the Research Ethics Committee of Minzu University (Approval: 2021/0725). The study adhered to the principles of the Declaration of Helsinki. Informed consent was obtained from all the subjects involved in the study. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JM: Writing – original draft, Writing – review & editing. AK: Writing – original draft, Writing – review & editing. H-JZ: Funding acquisition, Investigation, Supervision, Validation. ZJ: Data curation,

Formal analysis, Supervision, Validation, Visualization. MRA: Data curation, Funding acquisition, Investigation, Methodology, Software, Supervision, Conceptualization, Project administration, Writing – review & editing. MSA: Conceptualization, Data curation, Formal analysis, Supervision, Validation, Writing – review & editing. ET: Data curation, Formal analysis, Investigation, Project administration, Writing – review & editing. AA: Investigation, Software, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Psychological factors associated with vaccination hesitancy: an observational study of patients hospitalized for COVID-19 in a later phase of the pandemic in Italy

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Introduction: Vaccination against SARS-CoV-2 has been used to reduce the severity of COVID-19 disease and the incidence of new cases. However, a significant proportion of people have shown vaccination hesitancy.

Methods: This study explored psychological factors related to vaccination hesitancy in a sample of Italian COVID-19 patients (N = 54), hospitalized during 2021, after vaccines had been made available and while the vaccination campaign was on-going. Consecutive patients, aged 18 or older, admitted to the hospital with a diagnosis of COVID-19 were assessed with a set of standardized measures.

Results: In our sample, 48.1% was not vaccinated and 7.4% died within 6months after hospitalization, with a preponderance of deaths among non-vaccinated patients. Non-vaccinated participants had higher resilience scores at the CD-RISC-10 scale than vaccinated ones (33.6 $\pm$ 5.50 vs 28.6 $\pm$ 6.61; t40.2=+ 2.94, p = 0.005). No statistically significant differences were found between the two groups for any other measures.

Discussion: Higher levels of resilience among non-vaccinated patients may reflect greater identity worth and self-esteem, in turn resulting in a decrease in vaccination likelihood. This finding may have important public health implications, as it indicates that specific psychological aspects, such as resilience, may result in vaccination hesitancy, with implications for hospitalization rates, and thus healthcare costs, as well as loss of lives.

KEYWORDS

mental health, vaccination, vaccination hesitancy, COVID-19, resilience

1. Introduction

COVID-19 is the name of the disease caused by the new coronavirus SARS-CoV-2, discovered in China in December 2019. It was declared by the World Health Organization (WHO) to be a global pandemic in March 2020 (1). Over 600 million people have suffered from COVID-19 and almost 6 million have died by March 10th, 2023, because of the disease (2). The

virus spread very quickly around the world, resulting in the decision to implement restrictive measures by public health services, such as social and physical distancing, travel restrictions, use of personal protective equipment, confinement (quarantine), and hygiene measures. Common symptoms of COVID-19 include a dry cough, fever or chills, shortness of breath or difficulty breathing, muscle or body aches, sore throat, loss of taste or smell, diarrhea, headache, fatigue, nausea or vomiting, and congestion or a runny nose. However, the impact of COVID-10 has not been limited to physical health. The virus itself (direct effect) (3) and the measures applied by institutions (indirect effect) (4) have contributed to worsening the quality of life and mental health of the general population (5), along with a higher risk of relapse in individuals with mental health issues before the start of the pandemic (6). Vaccination against SARS-CoV-2 has been used to reduce the severity of COVID-19 disease and the incidence of new cases, leading to a significant change in the course of the pandemic and eventually relaxing restrictions and confinements. Moreover, it has been helpful to minimize possible permanent adverse health consequences and to avoid collapse of the health care systems. However, the success of a vaccination campaign does not depend only on its efficacy and safety, but also on the level of the vaccine acceptance, that may jeopardize the successful control of an infectious disease (7). Reaching out and vaccinating people who accept vaccination is obviously crucial, however the real challenge is to convince reluctant persons to vaccinate. Another factor that influenced the success of the vaccination campaign is represented by the introduction of certain laws that have contributed to increasing the vaccination rate in certain population groups (8, 9). Analyzing data from 33 countries, a recent systematic review found significant variation in terms of COVID-19 vaccine acceptance, with Italy being one of the countries with the lowest levels (10), possibly causing delays in reaching the target population immunization rate (11). Thus, studies are needed to identify predictors of vaccination hesitancy, including psychological characteristics (12), with the goal of mitigating its detrimental effects on control of infectious disease. The aim of the present study was to evaluate the prevalence of vaccination hesitancy in a cohort of COVID-19 hospitalized patients in Italy during a later phase of the pandemic, when the vaccine was already available, and the vaccination campaign was ongoing. Furthermore, the study aimed at identifying psychological factors associated with vaccination hesitancy.

2. Materials and methods

This is an observational study. It was conducted at the University hospital of Udine, a tertiary referral hospital of nearly 1,000 beds serving approximately 350,000 inhabitants, which has been appointed as regional hub for COVID-19 patients. The recruitment started on March 20th 2021 and ended December 31st 2022. All consecutive patients, aged 18 or older, admitted at the Infectious Disease Department with a diagnosis of COVID-19 confirmed by molecular swab, were considered eligible for inclusion. For those patients expressing willingness to participate, written informed consent was obtained before data collection. Since interviews were conducted via telephone, exclusion criteria included being unable to undertake a telephone interview due to any medical or psychological condition. The study was conducted in accordance with the Declaration of Helsinki and approved by the local Ethics Committee (CEUR-2021-OS-19).

2.1. Psychological assessment tools

Vaccination status for COVID-19 together with sociodemographic information were collected using an *ad hoc* form. Cognitive status was assessed with a back-translated version of the original English Telephone Interview for Cognitive Status (TICS) developed by Brandt in 1988 (13). TICS score ranges from 1 to 41 and comprises 11 items assessing orientation (personal, temporal, and spatial; score range: 0–12), attention and executive functioning (backward counting, backward calculation, abstraction; range: 0–9), language (naming to description, sentence repetition, and oral comprehension; range: 1–8), and memory (immediate recall, semantic memory; range: 0–12). Resilience was assessed with the Connor–Davidson resilience scale (CD-RISC-10). This is the abridged version of a 25-items self-report scale developed by Connor and Davidson in 2003 (14). It measures characteristics such as persistence, optimism, and confidence in ability to cope, with higher score indicating better resilience (15). Illness perception was assessed with the Brief illness perception questionnaire (IPQ-B), developed by Broadbent in 2006 (16). It is an eight-item scale that has each item rated on a scale from 0 (minimum) to 10 (maximum) and which assesses the emotional and cognitive aspects of an individual's illness. Each item of this questionnaire examines a dimension of understanding of the disease as follows: 1. Consequences; 2. Timeline; 3. Personal control; 4. Treatment control; 5. Identity; 6. Concern; 7. Illness comprehensibility; 8. Emotions. The IPQ-B also includes a question that is answered by the patient about one's opinion regarding the cause of illness. Items 1–5 assess the cognitive dimensions which relate to understanding of illness, its causes, and effect of treatment, while items 6 to 8 evaluate the emotional dimensions that relate to emotions such as mood, fear, anxiety, or anger. The total score of illness perception is calculated by inverting the score for items 3, 4 and 7 and added to the score of the other items. The maximum total score is 80 and the minimum total score is 0. A higher score indicates a more threatening view of the patient, while a lower score indicates a more optimistic view of the disease. Family function was assessed with the Family APGAR (17). It is a 5-item questionnaire (with each item rated on a 3-point scale) measuring five constructs: 1. Adaptability; 2. Partnership; 3. Growth; 4. Affection; and 5. Resolve. Scores range from 0 to 10 with higher scores indicating better functionality. Protective and risk factors after a potential traumatic event were assessed with the Global Psychodrama Screen (GPS, version 1.2), developed by the 'Global Collaboration on Traumatic Stress' (18). It consists of 22 items, 17 symptom items and 5 risk or protective factors, each to be answered in a yes/no format. The 17 symptom items assess: PTSD symptoms; affective dysregulation and negative self-concept; depression symptoms; anxiety symptoms; dissociation; sleep problems; self-injurious behavior; substance abuse; and other problems (physical, emotional, or social). The five risk or protective items assess other stressful events; social support; traumatic life events in childhood; history of psychiatric treatment; and resilience. The GPS total score is calculated using all 22 items, ranging 0–22. A total symptom score is the sum score of the 17 symptom items (range 0–17). A risk factor score is the sum score of the five risk or protective items (range 0–5). The Mini Locus of Control Scale (MLCS)

has been used to assess self-perception of control over external events (19). It consists of 6 items. People were asked to state their level of agreement according to a 4-point scale: totally (4); enough (3); little (2); not at all (1). It comprises three main subscales: 1. Fatalism, the random play of external circumstances ("There are those who are born lucky and those who are not"; "Without the right opportunities, it is difficult to succeed in life"); 2. Hetero-dependence, the influence exerted by the social environment ("My life is controlled mainly by the influence of other people"; "It is others who decide whether you succeed in your life or not"); and 3. Internality, the personal wills capabilities ("People could do so much more, if only they really tried"; "It's entirely up to me if I can take advantage of the opportunities life gives me").

2.2. Statistical analysis

Categorical measures were summarized with percentage frequencies; mean, standard deviation (SD), and range of variation were reported for continuous measures. Fisher's exact test was used in cross- tables with categorical measures (also reporting Odd-ratios, OR, with their 95% confidence interval, ci). In between-group comparisons, Welch's corrected t-test (or Mann–Whitney's test) or one-way analysis of variance were used with continuous measures (checking homoskedasticity with median-centered Levene's test). Also, Pearson's correlations were calculated (reporting estimated correlation with its 95% ci). Finally, multiple linear regression was fitted reporting its coefficient of determination (R^2; also adjusted for the number of covariates) and statistical significance; for predictors, tolerances and standardized coefficient (β) with statistical significance were reported. Pair-wise deletion on missing data was adopted. The statistical significance was set to $p < 0.050$. Analyzes were conducted with R-4.2.3 (R Development Core Team, 2023).

3. Results

3.1. Study participants

Sociodemographic and clinical characteristics of the sample, including details about vaccination status, are described in Table 1. Considering the overall sample, 48.1% of patients were not vaccinated. 7.4% of participants died within 6 months after hospitalization [3.2 ± 1.78 (1.2, 5.0) months]. It was observed a preponderance of deaths in the non-vaccinated group (16.7%) when compared with the vaccinated group [2.8%; OR = 6.727 (IC 95% 0.495, 376.765)]. No statistically significant differences were observed between participants who have been vaccinated and those who were not for age at hospitalization (U = 276.0, $p = 0.944$), sex [OR = 1.528 (IC 95% 0.360, 7.842)], being single [OR = 1.118 (IC 95% 0.304, 4.044)], living alone [OR = 1.898 (IC 95% 0.385, 9.073)], having a low-level of schooling [OR = 0.468 (IC 95% 0.092, 1.948)], working [OR = 0.705 (IC 95% 0.175, 2.612)], having physical comorbidities [OR = 1.000 (IC 95% 0.181, 7.039)], being under psychopharmacological treatment [OR = 2.699 (IC 95% 0.269, 137.102)], and duration of hospitalization ($t_{27.4} = +0.23$, $p = 0.821$).

TABLE 1 Sample description and vaccination status.

	% or Mean ± SD [min, Max]
Number of observations	54
	% or Mean ± SD [min, Max]
Sex	*Female*: 27.8%
Age at hospitalization	62.4 ± 12.58 [27, 85]
Marital status	*Single*: 22.2%
	Couple/Married: 57.4%
	Separated/Divorced: 14.8%
	Widower/Widow: 5.6%
Living situation	*Lives alone*: 20.4%
	Lives with family: 74.1%
	Other living situation: 5.6%
Schooling	*Primary*: 7.7%
	Middle: 25.0%
	High: 55.8%
	Degree: 11.5%
Work situation	*Retired*: 48.1%
	Employed: 38.9%
	Unemployed: 9.3%
	Housewife: 3.7%
Has physical comorbidity	83.3%
Psychopharmacological therapy	*No*: 88.9%
	Sleeping medication: 7.4%
	Antidepressants: 1.9%
	Other medication: 1.9%
Days of hospitalization	17.8 ± 17.98 [2, 84]
Vaccination status	*Before hospitalization*: 51.9%
	After hospitalization: 14.8%
	Never: 33.3%
Details	*Single dose*: 7.4%
	Two doses: 20.4%
	Three doses: 38.9%

Max, Maximum observed value; min, minimum observed value; SD, Standard Deviation.

3.2. Psychological assessments

Results of the self-assessment tests are provided in Table 2. Non-vaccinated participants had higher total scores at the CD-RISC-10 than vaccinated ones (33.6 ± 5.50 vs. 28.6 ± 6.61; $t_{40.2} = +2.94$, $p = 0.005$), in particular they were less represented in the lower quartile [16.6% vs. 83.3%; OR = 0.235 (IC 95% 0.047, 0.943)], without statistically significant differences for distribution in other quartiles (all with $p \geq 0.273$; Table 3). Instead, no statistically significant differences resulted between the two groups for having an internal locus of control [MLCS: OR = 1.488 (IC 95% 0.352, 6.024)], for cognitive status (I-TIC: $t_{47.8} = +0.68$, $p = 0.498$), for having a dysfunctional family [Family-Apgar: OR = 1.488 (IC 95% 0.352,

TABLE 2 Sample description and vaccination status.

Test		% or Mean ± SD [min, Max]
CD-RISC-10	Total score	30.22 ± 6.652 [15.00, 40.00]
	Quartile of resilience	*1st quartile [0, 29]*: 44.4%
		2nd quartile [30, 32]: 16.7%
		3rd quartile [33, 36]: 20.4%
		4th quartile [37, 40]: 18.5%
MLCS	Classification	*Fatalist internalist*: 64.8%
		Pure internalist: 27.8%
		Heterodependent fatalist: 5.6%
		Pure fatalist: 1.9%
I-TIC	Total score	35.7 ± 5.32 [21, 48]
Family-Apgar	Classification	*Functional*: 84.4%
		Moderately difunctional: 11.1%
		Severely dysfunctional: 4.4%
Brief-IPQ	Total score	33.0 ± 15.14 [0, 68]
	1. Consequences	5.2 ± 3.57 [0, 10]
	2. Timeline	3.5 ± 3.33 [0, 10]
	3. Personal control⁺	5.5 ± 3.53 [0, 10]
	4. Therapy control⁺	6.7 ± 3.52 [0, 10]
	5. Intensity	3.3 ± 3.43 [0, 10]
	6. Concern	4.7 ± 3.48 [0, 10]
	7. Coherence⁺	5.3 ± 2.97 [0, 10]
	8. Emotions	3.8 ± 3.47 [0, 10]
GPS	Total symptoms	3.6 ± 2.95 [0, 12]
	PTSD	1.1 ± 1.28 [0, 5]
	CPTSD	1.5 ± 1.58 [0, 6]
	Risk	1.0 ± 1.17 [0, 4]
	DSO	0.4 ± 0.63 [0, 2]
	Anx	0.7 ± 0.65 [0, 2]
	Dep	0.6 ± 0.66 [0, 2]
	Ins	0.3 ± 0.46 [0, 1]
	SHI	0.0 [0, 0]
	Dis	0.1 ± 0.32 [0, 1]
	Sub	0.1 ± 0.23 [0, 1]
	Other problems	0.3 ± 0.44 [0, 1]

⁺: Higher scores are advantageous (Brief-IPQ); Anx, Anxiety items (GPS); Brief-IPQ: Brief Illness Perception Questionnaire; CD- RISC-10: Connor-Davidson's Resilience Scale, 10-items; CPTSD: Complex Post-Traumatic Stress Disorder scale (GPS); Dep: Depression items (GPS); Dis: Dissociation items (GPS); DSO: Disturbances in Self-Organization items (GPS); Family-Apgar: Family Apgar; GPS: Global Psychodrama Screen, version 1.2; I-TIC: Telephone Interview for Cognitive Status, Italian version; Ins: Insomnia item (GPS); Max: Maximum observed value; min: minimum observed value; MLCS: Mini Locus of Control Scale; N: Number of observations; PTSD: Post-Traumatic Stress Disorder scale (GPS); Risk: Risks and protective factors scale (GPS); SD: Standard Deviation; SHI: Self-Harm Ideation item (GPS); Sub: Substance misuse item (GPS).

6.024)], for illness perception (Brief-IPQ total score: $t_{37.0} = +0.06$, $p = 0.954$; with $p \geq 0.091$, for single items), and for presenting with psycho-traumatic symptoms (GPS symptoms: $t_{33.8} = -0.55$, $p = 0.587$; with $p \geq 0.083$, for sub-scales and specific symptoms). Going into more detail (see Figure 1), the number of vaccine doses was significantly associated to the total CD- RISC-10 score ($F_{3,50} = 3.91$, $p = 0.014$), lowering from those who had not been vaccinated (33.6 ± 5.50) to those who had received three doses [27.0 ± 6.33; in post-hoc: $\Delta = +6.6$ (+1.3, +11.9), $p = 0.009$]. Consistently, considering the distinction between participants who were vaccinated before hospitalization (i; CD-RISC-10: 28.1 ± 6.41), those vaccinated after hospitalization (ii; 30.3 ± 7.48), and those never vaccinated (iii; 33.6 ± 5.50), we observed a statistically significant difference ($F_{2,51} = 4.17$, $p = 0.021$), in particular between those vaccinated before hospitalization and those never vaccinated [$\Delta = +5.5$ (+0.9, +10.1), $p = 0.015$].

TABLE 3 Vaccination by quartile of resilience (CD-RISC-10 total score).

Quartile of Vaccination status *(in relation to hospitalization)*			
Resilience	*Before*	*After*	*Never*
1st, score: [0, 29]	66.7%	16.7%	16.7%
2nd, score: [30, 32]	55.6%	-	44.4%
3rd, score: [33, 36]	36.4%	18.2%	45.5%
4th, score: [37, 40]	30.0%	20.0%	50.0%

CD-RISC-10: Connor-Davidson's Resilience Scale, 10-items.

3.3. Exploratory analyzes of resilience score predictors

The CD-RISC-10 total score was not associated with age at hospitalization [$r = -0.130$ (−0.392, +0.151)], being single ($t_{44.4} = +0.09$), living alone ($t_{13.4} = +1.04$), having a low-level of schooling ($t_{28.3} = +0.81$), working ($t_{46.1} = -1.77$), having physical comorbidities ($t_{11.3} = -1.42$), being under psychopharmacological treatment (U = 126.0) and duration of hospitalization [$r = -0.049$ (−0.326, +0.235)]. Resilience was also not significantly associated with internal locus of control at the MLCS ($t_{33.5} = -0.70$) or symptoms at the GPS [$r = -0.198$ (−0.442, +0.074)]. Instead, males scored higher than females (31.4 ± 6.47 vs. 27.1 ± 6.30; $t_{26.1} = -2.22$) and the resilience score was found to be associated with the I-TIC score [$r = +0.407$ (+0.151, +0.612)], having a dysfunctional family according to the Family-Apgar questionnaire ($t_{7.5} = +2.62$) and the Brief-IPQ score [$r = -0.293$ (−0.520, −0.028)]. When statistically significant moderators were considered together (tolerance ranging between 0.819 and 0.976), the multiple regression was statistically significant ($R^2 = 0.568$, adjusted to 0.510; $F_{5,37} = 9.75$). As can be seen in Figure 2, not being vaccinated was still shown to have a statistically significant association with resilience score ($\beta = +0.771$), cognitive status (I-TIC score: $\beta = +0.412$) and having a dysfunctional family (Family-Apgar: $\beta = -1.062$). The introduction of covariates reduced the β of vaccination by 7.9%.

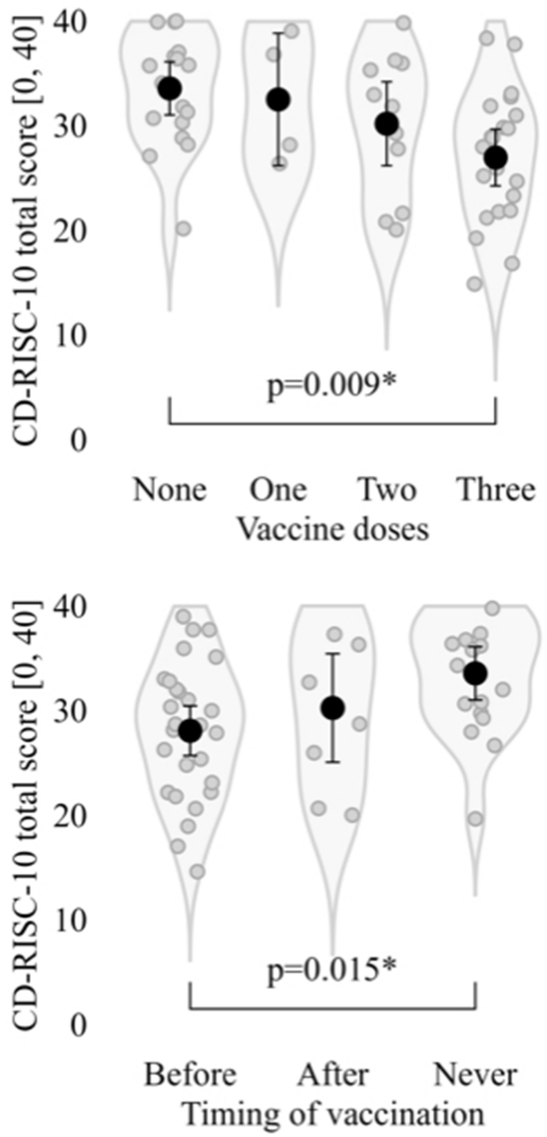

FIGURE 1
Total score at CD-RISC-10 by number of vaccine doses and timing of vaccination with reference to hospitalization. CD-RISC-10: Connor-Davidson's Resilience Scale, 10-items. *: Statistically significant with *p*.

4. Discussion

The COVID-19 global health emergency officially started on January 30th 2020 and ended on May 5th 2023. Incidence rates fluctuated over time and in Italy have been divided into four waves (20). The first wave happened during February–May 2020, the second during October–December 2020, the third during January–May 2021 and the fourth during November 2021–March 2022. The vaccination campaign started on December 27th 2020 and is still ongoing. This study has been conducted between the third and the fourth wave, when the percentage of vaccinated people increased from 24 to 80% (21), achieving the target population immunization rate (22). In the overall sample, 48.1% of patients were not vaccinated (i.e., with a ratio of 1.1 vaccinated persons for every non-vaccinated person), against an expectation of 15.9% (i.e., expected ratio: 5.3) (23). Such finding is in line with the higher risk of suffering from a form of COVID-19 requiring hospitalization among non-vaccinated individuals found in the relevant literature (24). A clinically significant higher mortality was also observed among non-vaccinated individuals (24). In a study conducted in 26 European countries in the same time period, the percentage of people declining COVID-19 vaccination was around 26% (25). Despite vaccination being among the key strategies implemented to limit the spread of the virus and improve health outcomes and life expectancy (26), a significant proportion of people have shown high levels of hesitancy. Vaccine hesitancy is a complex phenomenon, and it is influenced by several factors, including perceived need for the vaccine, accessibility of the vaccine, and perceived benefits and safety of the vaccine (25). Reduced vaccination intentions have been associated with female gender (27–33), high trust in media information sources (29, 34), low levels of trust in information from government sources, high conspiracy-mindedness (29), fear of side effects, and preference for a natural lifestyle (35). On the contrary, willingness to receive the vaccine has been associated with high education, high economic status, high perceived risk of infection (36–38), living with people with poor health, viewing vaccinations as a moral norm (39), positive attitude toward vaccines and previous vaccination (40), fear of COVID-19 and high levels of resilience (41). This study did not find any association between vaccination hesitancy and gender, economic status, and level of education. However, higher levels of resilience were found among non-vaccinated people, and such a result is worth of attention. Resilience refers to the process of bouncing back from difficult experiences and adapting well in the face of adversity, trauma, tragedy, threats, or significant sources of stress (42). It can be conceptualized at the individual (i.e., a stable trajectory of healthy functioning after a highly adverse event) (43), community (i.e., the success of the community to provide for the needs of its members and the extent to which individuals are helped by their community) (44), and societal (i.e., the perceived ability of the society to successfully deal with adversities and quickly recover after the threat has been removed) (45) levels. Individual resilience is closely related to identity resilience, that reflects the individual's subjective belief in their capacity to understand and overcome challenges, their self-worth and value, their positive distinctiveness from others, and their certainty about who they have been and will remain (46). Identity resilience has two key components, which are *identity worth*, comprising self-efficacy, self-esteem, and positive distinctiveness, and *identity continuity*, depending upon feeling that the uniqueness and meaning of their identity persists over time (46). Regarding COVID-19, it has been found that identity worth is associated with less COVID-19 fear and less perceived COVID-19 risk, which could possibly result in a decrease in vaccination likelihood. One of the elements that define identity worth is self-esteem, and high levels of self-esteem have been associated with both healthy behaviors (47) and reduced probability of influenza vaccination (48). This has been explained by the tendency of individuals with high self-esteem to ignore disagreeable information and assume that calamities cannot happen, which can lead to declining vaccination (47). Thus, we can speculate that high levels of resilience among non-vaccinated people in our sample may be explained by high levels of identity worth and self-esteem.

It is worth mentioning that the high levels of vaccination hesitancy in our sample may result from the complex Italian

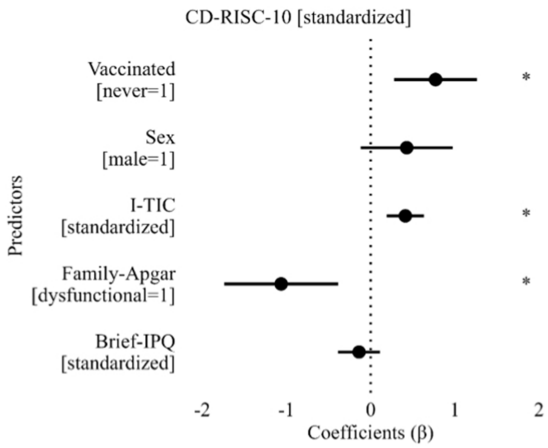

FIGURE 2
Results of multiple linear regression for CD-RISC-10 score. Brief-IPQ: Brief Illness Perception Questionnaire; CD-RISC-10: Connor-Davidson's Resilience Scale, 10-items; Family-Apgar: Family Apgar; I-TIC: Telephone Interview for Cognitive Status, Italian version. *: Statistically significant predictor with *p*.

sociopolitical situation during the pandemic. Italy was the first European country to be hit by the COVID-19 and since then several television personalities, politicians, media outlets, and even scientists have contributed to spreading conflicting and misleading information (49). This has generated a climate of uncertainty that has compromised trust in institutions, whose non- pharmacological interventions were often cataloged as exaggerated, and altered the risk perception of the population (50). The lack for trust in institutions has been related with an increase in vaccination hesitancy (51).

Limitations of this study include the single assessment performed during COVID-19-related hospitalization. In the absence of resilience information obtained outside of such a context, a confounding effect of hospitalization for COVID-19 cannot be ruled out. This may be particularly relevant for vaccinated individuals, whose resilience may have suffered a reduction for failing to avoid hospitalization despite having received one or more vaccine doses. Nevertheless, the current work may have important public health implications, as it indicates that specific psychological aspects, such as resilience, may modulate vaccination hesitancy, with implications for hospitalization rates, and thus healthcare costs, as well as loss of lives.

5. Conclusion

We carried out an observational study in order to explore psychological factors related to vaccination hesitancy in a sample of patients hospitalized for COVID-19 in a later phase of the pandemic when vaccines had been made fully available to the general population. We found higher resilience scores in non-vaccinated patients compared to vaccinated ones. This result may be explained by high levels of identity worth and self-esteem among non-vaccinated people, making them less prone to vaccination. Future studies will have to focus not only on psychological but also on broader socio-behavioral determinants of compliance with health and mental care recommendations (e.g., lack of trust in institutions), in order to better understand the vaccination hesitancy phenomenon.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Unique Regional Ethics Commitee (CEUR-2021-OS-19). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CC: Conceptualization, Data curation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. MCe: Conceptualization, Data curation, Investigation, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. RM: Conceptualization, Data curation, Investigation, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. MG: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. RB: Conceptualization, Data curation, Investigation, Validation, Visualization, Writing – review & editing. NI: Conceptualization, Data curation, Investigation, Resources, Validation, Visualization, Writing – review & editing. ES: Conceptualization, Resources, Validation, Visualization, Writing – review & editing. CT: Conceptualization, Resources, Supervision, Validation, Visualization, Writing – review & editing. MB: Conceptualization, Data curation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. MCo: Conceptualization, Data curation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

CT has received grants in the last 2 years from Correvio, Biotest, Biomerieux, Gilead, Angelini, Pfizer, Thermofisher, Zambon, Shionogi, Avir Pharma, and Hikma, outside of this work. MCo has been a consultant/advisor to GW Pharma Limited, GW Pharma Italy SRL, and F. Hoffmann-La Roche Limited, outside of this work.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Subjective assessment of occupational stress and mental health of nurses during the Covid-19 pandemic period

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Introduction: Health status, sickness absence, and nurses' attrition have a direct impact on the quality of care provided and patients' health outcomes. The Covid-19 pandemic exacerbated issues that existed within the Polish healthcare system prior to the pandemic, including staff shortages, low wages, and system inadequacies. The aim of this study was to investigate how nurses during the Covid-19 pandemic period rated the burdensomeness of job characteristics and their mental health status, as well as the correlations between factors directly caused by the Covid-19 pandemic and nurses' subjective assessments of job characteristics and mental health.

Method: The cross-sectional study was conducted in January 2022, in Poland and involved 796 registered nurses working in hospitals.

Results: Despite the pandemic's sweeping societal effects, this research finds limited alteration in nurses' perceptions of job stress and self-assessed mental health. Factors such as contact with infected patients, quarantine, and isolation do not appear to substantially modify mental health perceptions among nurses. Intriguingly, nurses subjected to COVID-19 testing report heightened stress and compromised mental health.

Conclusion: The interplay of diverse factors influencing the well-being of nurses is intricately complex. It is advisable to prudently execute interventions and strategies to address the pandemic, aiming to alleviate its potential adverse effects on the mental health of nurses.

KEYWORDS

stress, nurse, mental health, anxiety, depression, insomnia, work characteristics, COVID-19

1 Introduction

Psychosocial determinants exert an adverse influence on employee well-being by inducing stress. These factors arise within distinct organizational and societal frameworks, their character molded by the subjective psychological appraisal of their relevance by the individual (1, 2). These factors can manifest as threats, constraints, value deprivations, or challenges to an individual's abilities and aspirations (3). Psychosocial stimuli inherently display subjectivity. The potential for a specific aspect of a work environment to evolve into a psychosocial stressor is contingent upon

the unique attributes of both the individual and the collective group within which the individual operates. The significance of a given factor for an employee hinges upon these contextual elements (4). Numerous studies reported that stressors occurring at work have a negative impact on the employee health (4–6). Psychosocial factors affect employees' health by triggering a stress reaction that lasts for a long time (7). The effects of this reaction may be reflected in disorders of various systems and body functions. Therefore, it is not possible to establish a specific link between a specific psychosocial factor and the incidence of a specific disease (8).

The perception of workplace burdens is a subjective feeling, which has been confirmed by theories of occupational stress. The high social expectations and high professional demands placed on nurses by hospital managers and the relatively low salaries offered perfectly match the theory of the fit between the individual and the environment by French et al. (9), as well as Siegriest's disequilibrium model (10).

French's theory revolves around two fundamental components: the employee's attitude level and their capacity to fulfill job requirements. Within this theory, a clear distinction is drawn between the objective reality of changes in the environment and the subjective perception thereof. Objective alignment relies on externally defined criteria, such as experience, education, and skills, which are typically evaluated by external experts, such as during a job interview. On the other hand, subjective alignment pertains exclusively to the individual attributes of the employee and their personal perception of the work environment. Mismatches can manifest in various patterns, each potentially influencing the level of stress experienced by the employee (9).

Siegirist's model (10) illustrates the discrepancy between the effort invested in a job and the rewards obtained in return. The degree of effort is contingent upon two primary factors: the inherent demands of the job and the individual's unique traits. Compensation for work encompasses three dimensions: financial remuneration and professional standing, recognition and support, and job stability and prospects for career advancement. When an employee becomes overly engrossed in their work, all the while undervaluing the rewards they receive, an imbalance between effort and reward emerges, resulting in a stressful situation (11).

We conducted the study on nurses, because it is nurses who are the most stressed group of health care workers, and one of the most stressed professional groups globally (12). Somatic and psychological stress-related illness indices are higher among nurses than in the general population (13, 14). Psychosocial burdens affect the development of anxiety, insomnia, excessive sleepiness and depression among nurses (15). The effects of loads manifest themselves as undesirable behaviors at work such as avoidance, increased irritability, cynical attitude. Any workload that occurs at work and exceeds the employee's ability to cope with the workload is associated with absenteeism, change or resignation from work. Some nurses excessively use sick leave to avoid psychological strain at work (16–18). In Poland, a significant percentage of nurses leave the profession within 10 years of obtaining their professional qualifications. The main reasons for leaving the profession are low wages, difficult working conditions and poor health (19).

The work of a nurse is complex and involves multi-tasking. It requires a high level of manual dexterity for treatment and nursing activities, the meticulousness necessary for medical record keeping, the technical knowledge necessary for operating medical equipment and devices, interpersonal skills for collecting patient health history, patient health education and communication with their families. (20, 21).

Sources of stress experienced by nurses include poorly organized work, shift-based work that disrupts the natural biological rhythm of the body's, irregular work that causes periodic high overloads, lack of satisfactory pay, lack of recognition from superiors, and lack of career development prospects. Nurses working in units with a significant risk of contact with chronic dying and death declare that the greatest sources of stress in their professional pacing include: dying and death of the patient, watching the development of the disease and its consequences, and the nurse–patient-family relationship (22). Direct contact with potentially infectious materials from the patient (blood, secretions, excretions) is an important source of stress (23). There is also often time pressure, as unpredictable situations arise, such as the sudden deterioration of a patient's condition or resuscitation, wherein pure minutes are decisive for the life of the patient (24). There are also situations involving a sense of no control, such as when caring for an unconscious or intubated patient. At such time, the nurse has no opportunity to interact with the patient and get feedback on whether her work is having the intended effect. Many problems stem from nurses' relationships with colleagues, patients and their families, which sometimes take place in an atmosphere of high emotional tension (22, 25).

When listing sources of stress at nursing work, it is important to emphasize the wide range of responsibilities associated with their professional duties, the pressure to be reliable and available, and the expectations of patients and their families (26). Society's expectations of nurses are significantly different from feelings of nurses themselves. Societies expect nurses to express only those emotions that alleviate the fear and suffering of the patient and his family (27).

The COVID-19 pandemic has become an additional source of stress for health care workers including nurses what was confirmed in numerous studies (28–30). The pandemic brought a number of stressors to which health workers were exposed in the workplace. These included a high mortality rate for COVID-19 patients, more overtime shifts, fear of lack of appropriate medical equipment (including personal protective equipment), constant testing, quarantines, being in home isolation, contact with infected patients, infection by virus, risk of transmission to family members, fear of the viral spread at the workplace, lack of access to child care when working overtime or when schools were closed, as well as lack of support for other personal and family issues when faced with work demand increase (30, 31). Negative psychological factors were further exacerbated by media coverage of the pandemic, which focused on mortality among health care workers, and the disease in spread health care facilities (29).

As per the Centers for Disease Control and Prevention's findings, healthcare professionals have undergone a decline in psychosocial work attributes, evidenced by deteriorating work environments, heightened irritability, reduced motivation, sensations of inadequacy, depressive symptoms, emotional overload, burnout, sleep disturbances, impaired interpersonal relationships, sensations of fatigue, feelings of being overburdened, and perceived threats (32).

We observed a paucity of research in the existing literature concerning the influence of the COVID-19 pandemic on the subjective perception of work characteristics and the mental well-being of Polish nurses. Consequently, we undertook an investigation to examine the potential associations between stressors unique to the COVID-19 crisis, namely, exposure to Sars-Cov-2-infected patients, extensive virus testing, quarantine, home isolation, and Sars-Cov-2

infection, and the subjective evaluation of psychosocial working conditions and the self-assessment of mental health among Polish nursing professionals.

2 Materials and methods

The cross-sectional study was executed in January 2022 within the Podlaskie Voivodeship in Poland. The participant cohort comprised 796 registered nurses employed at the Bialystok University Clinical Hospital and the Provincial Hospital in Lomza. The study protocols received endorsement from the Bioethical Commission of the Medical University of Bialystok, under reference no. APK.002.518.2021. All procedures undertaken during the investigation adhered to internationally recognized ethical principles governing research involving human subjects, encompassing aspects such as voluntary participation, informed consent, assurance of anonymity and confidentiality, mitigation of potential harm, and appropriate dissemination of results.

2.1 Study group selection

Owing to limitations in hospital accessibility in Poland during the study period, coupled with logistical challenges in arranging in-person encounters, the investigation was restricted to two hospitals located in Bialystok, the provincial capital, and Lomza, the second largest city within the province. The eligibility criteria for inclusion encompassed individuals employed within the hospital under a full-time contractual agreement. Nurses engaged in part-time roles or operating under contractual arrangements distinct from full-time employment were excluded from the study.

2.2 Study protocol

The study utilized paper-based questionnaires, which were delivered by the researchers to the hospital and subsequently disseminated to the intended participants by departmental nurses. Voluntary participation was emphasized throughout the study. Prior to commencement, all nurses were duly informed of the anonymous nature of the research and were assured of their prerogative to withdraw without the obligation of providing a rationale. They were instructed to complete the questionnaires at their convenience within a one-week timeframe and to return the finalized surveys in securely sealed envelopes. A total of one thousand questionnaire surveys were distributed across both hospital settings, yielding a response rate of 79.6% with 796 accurately completed questionnaires returned. The reasons underlying the non-participation of 204 respondents remain undisclosed. Demographic and occupational data were exclusively obtained from self-reported information provided within the surveys. The utilization of incentives to encourage study participation was not implemented.

2.3 Study group

The cohort under investigation comprised 796 nurses. A significant majority of the participants were female (94.1%). Nurses aged below 34 accounted for 35.2% of the sample, while those aged 51 and above represented 22.7% of the respondents. The mean age of the surveyed nurses was 41.5 years, with a standard deviation of 11.8 years. Furthermore, a notable 77.8% of the respondents had attained higher nursing education. Those with less than 6 years of work experience constituted 30.7% of the cohort, whereas individuals with over 17 years of experience comprised 39.7% of the participants.

2.4 Description of the questionnaire and the applied measures

The instrument employed for evaluating the health status was the Goldberg General Health Questionnaire GHQ-28, adapted for use in Poland by Makowska and Merecz (33). The GHQ-28 questionnaire serves as a tool for appraising the mental well-being of adult individuals, facilitating the identification of individuals whose mental states have been subject to temporary or enduring impairment due to life challenges, adversities, or mental disorders, as well as those at a significant risk of mental health complications. Apart from its overall scoring, the GHQ-28 questionnaire comprises four distinct scales, namely somatic symptoms, anxiety/insomnia, social dysfunction, and severe depression symptoms. The severity of these adverse mental states is evaluated by aggregating responses to specific queries, coded using a dichotomous system. The sample queries are: *have you had headaches recently?, have you been getting irritated and angry recently?, have you felt that what you are doing is useful recently?, have you felt that life is not worth living recently?*. The individual domain measures range from 0 to 7 points, while the total measures range from 0 to 28 points. Higher GHQ values are indicative of poorer mental health. The authors of the questionnaire have standardized these measures. Both the original GHQ-28 and its Polish adaptation have undergone extensive validation and are accompanied by clear scoring guidelines (34). The GHQ-28 questionnaire was also validated using data obtained from the study group, calculating the value of the Cronbach's Alpha coefficient for the component measures and for the overall measure. The obtained results: somatic symptoms – 0.860, anxiety/insomnia – 0.893, social dysfunction – 0.848, severe depression – 0.890, total – 0.937, have very high values, confirming the desired psychometric properties of the GHQ-28 questionnaire.

The Subjective Work Evaluation Questionnaire (SWEQ) developed by Dudek and Waszkowska was administered to evaluate subjective work attributes (8). This tool serves to gage the subjective perception of work and is specifically designed to quantify employees' personal experience of occupational stress. Comprising 50 statements delineating various job characteristics, each statement is accompanied by a numerical scale ranging from 1 to 5. The sample statements of the questionnaire are: *my job requires vigilance,* i.e., *readiness to react quickly to an important signal that may appear at any moment, working in my position, I do not have information about whether what I do is done well or poorly, in my work, I receive tasks that require me to compete with others, I sometimes come home with a sense of task non-completion.* This scale enables respondents to indicate the degree to which a particular attribute is perceived as burdensome. Notably, a rating of 1 implies the absence of the specific attribute within the job, while a rating of 5 signifies the highest level of perceived adversity. The questionnaire has undergone rigorous validation and is accompanied by clearly defined scoring protocols (8). The SWEQ questionnaire was

also validated using results from the study group, calculating the value of the Cronbach's Alpha coefficient for the overall measure and component measures. The obtained results (for the overall measure of general stress – 0.961, and for the specific measures ranging from 0.650 to 0.868) have very high values, indicating the desired psychometric properties of the SWEQ questionnaire.

2.5 Statistical methods

In the descriptive segment, we have presented an array of the community under examination, delineated in the form of tables incorporating numerical descriptors for quantitative attributes or percentage distributions for select characteristics.

We used the Mann–Whitney test to assess the significance of differences between the two groups, where one experienced a certain factor and the other did not. We analyzed the relationship between two numerical (ordinal) characteristics by determining the values of Spearman's rank correlation coefficient (rS) and supplemented it with the results of the correlation coefficient significance test (p).

We used regression analysis to describe the impact of COVID-19 pandemic-related and psychosocial factors on all measures of workload in the SWEQ, and the overall measure of mental health assessment with the GHQ-28 questionnaire. Using the procedures of searching for the optimal model (stepwise regression, search for the best subset), we selected the factors that affect each measure in a statistically significant way. We then presented these models in the results and subjected them to interpretation.

3 Results

3.1 Subjective evaluation of negative work characteristics

The negative aspects of nurses' work were subjectively assessed using the 50-item SWEQ questionnaire. This assessment served as the foundation for calculating score-based workload measures across 10 selected dimensions (6). These measures possess a pejorative nature, where higher values indicate a less favorable evaluation of work outcomes. Table 1 provides details on the distribution of numerical measures related to work characteristics.

The SWEQ questionnaire did not incorporate standardization measures from its authors, thus precluding direct comparisons. However, point thresholds were established for each questionnaire measure, and surpassing these thresholds signified the presence of adverse working conditions in a particular domain. Consequently, individuals falling into this category were identified as having a high level of negative work attributes according to the questionnaire's creators' criteria (6). Table 2 offers a summary of the figures and percentages of individuals exhibiting a high level of negative assessments pertaining to specific work aspects. The results, excluding overall stress, were ranked based on the frequency with which particular negative characteristics were reported, from the most commonly cited to the least frequently mentioned by respondents.

3.2 General mental health of the nurses

The numerical characteristics of the GHQ-28 measures are shown in Table 3. Each measure takes values from 0 to 7 points, while the summary measure takes values from 0 to 28 points. Comparing the mean values with the median, it can be seen that all measures have a very asymmetric distribution – the means are much higher than the median, which is 0 for the two measures more related to mental aspects, meaning that most of the people surveyed do not show any negative symptoms in these areas. According to our results, the GHQ-28 summary measure alone has slightly less asymmetry. Such a significant asymmetry markedly limits the ability to analyze detailed GHQ measures, as they simply show little variability.

3.3 The COVID-19 pandemic and psychometric measures

We analyzed the impact of selected factors resulting from the ongoing COVID-19 pandemic on individual measures of subjective evaluation of working conditions (SWEQ) and nurses' self-assessment of health (GHQ-28) in detail. We used the Mann–Whitney test to

TABLE 1 Subjective evaluation of negative work features.

Subjective work evaluation questionnaire	$\bar{x}$	Me	s	Min	Max	A
General stress	117.1	110	35.0	60	275	1.19
Work overload	19.3	18	6.8	–	45	0.96
Lack of rewards	16.3	15	6.7	8	40	0.92
Uncertainty in workplace	16.2	15	5.6	7	35	0.76
Social relations	10.6	–	3.3	5	25	1.65
Threat	11.9	11	3.8	5	25	0.75
Physical burdens	8.0	8	4.7	4	20	0.87
Unpleasant work conditions	5.2	3	3.2	3	15	1.32
Lack of control	8.7	8	2.7	4	20	1.74
Lack of support	5.4	5	2.4	3	15	1.18
Responsibility	9.2	–	3.0	4	20	0.86

assess the significance of differences between groups declaring contact with a given pandemic agent or lack thereof.

3.3.1 Subjective evaluation of nurses' work during the COVID-19 pandemic period

3.3.1.1 Contact with a patient diagnosed with SARS-CoV-2 virus infection

We found no major differences in the assessment of psychosocial burden at work according to contact with a patient diagnosed with SARS-CoV-2 virus infection. The sense of no control was the only aspect significantly higher in those who have had contact with a patient diagnosed with SARS-CoV-2 virus infection than in those who have not had such contact.

3.3.1.2 Home isolation

We found no major differences in the assessment of psychosocial burdens at work depending on whether home isolation was implemented or not. According to the outcome of the survey, home isolation only slightly differentiates feelings of responsibility (negative feelings in this aspect are higher among nurses who have been in home isolation).

3.3.1.3 Staying in quarantine

Staying in quarantine does not differentiate any of the measures for assessing working conditions.

TABLE 2 Number and percentage of people with high levels of negative work characteristics.

Subjective work evaluation (negative ratings)	Count	Percentage[1]
Social relations	619	77.8%
Threat	562	70.6%
Responsibility	560	70.4%
Work overload	500	62.8%
Lack of control	472	59.3%
Lack of rewards	470	59.0%
Uncertainty in workplace	448	56.3%
Lack of support	445	55.9%
Physical burdens	408	51.3%
Unpleasant working conditions	316	39.7%
General stress	500	62.8%
No negative ratings	29	3.6%

[1]The total does not have to be 100% because the test subjects could indicate any number of response options.

3.3.1.4 SARS-CoV-2 test performed

Performing the SARS-CoV-2 virus test was the only pandemic factor that differentiated the group of nurses testing for COVID-19 from the non-testing group, which constituted a much smaller group. Those testing experienced higher levels of general stress, uncertainty in the workplace, threat and discomfort in the area of responsibility. The difference in the category of unpleasant working conditions is also on the verge of statistical significance. Detailed data are shown in Table 4.

3.3.1.5 COVID-19 virus infection

We found no major differences in the assessment of psychosocial burden depending on the history of SARS-CoV-2 virus infection. Only COVID-19 survivors had a greater sense of discomfort at work in the categories of social relations and responsibility.

3.3.2 Mental health assessment of nurses during COVID-19 pandemic period

3.3.2.1 Contact with a patient diagnosed with SARS-CoV-2 virus infection

We found no major differences in nurses' assessments of mental health according to contact with patients diagnosed with SARS-CoV-2 virus infection. Only nurses who had contact with a patient diagnosed with SARS-CoV-2 virus infection had more severe somatic symptoms (statistically significant difference) than those who had no such contact.

3.3.2.2 Home isolation

Being subject to home isolation did not affect the nurses' self-assessment of mental health.

3.3.2.3 Staying in quarantine

Being in quarantine did not affect the nurses' self-assessment of their mental health.

3.3.2.4 SARS-CoV-2 test performed

Nurses who were tested for SARS-CoV-2 have much stronger levels of anxiety and insomnia, and also have significantly stronger somatic symptoms. The overall health score is also significantly worse in this group. Detailed data are shown in Table 5.

3.3.2.5 SARS-CoV-2 virus infection

We found no major differences in mental health scores depending on the history of SARS-CoV-2 virus infection. Only the past SARS-CoV-2 infection is associated with slightly stronger symptoms of depression, although the difference is not very statistically pronounced.

TABLE 3 General mental health of the nurses.

GHQ-28	$\bar{x}$	Me	s	Min	Max	A
Somatic symptoms	2.05	1	2.20	0	7	0.84
Anxiety/insomnia	1.87	1	2.23	0	7	0.96
Social dysfunction	1.12	0	1.83	0	7	1.80
Severe depression	0.38	0	1.13	0	7	3.74
Total	**5.42**	**3**	**6.21**	**0**	**28**	**1.34**

3.4 Multivariate analysis

3.4.1 Factors affecting subjective measures of stress at work

Using regression analysis, we constructed models to describe the effects of socio-professional factors (age, years of work, education, work system) and SARS-CoV-2-related factors on all subjective measures of work stress. Employing the procedures of searching for the optimal model (stepwise regression, search for the best subset), we then selected those factors that affect each measure in a statistically significant way.

Among the socio-occupational factors, only years of work and 12-h (vs. 8 h) work system resulted in experiencing greater general stress, work overload, lack of rewards, uncertainty in workplace, social relations and feeling of threat. For factors related to the pandemic, correlations occurred only for being tested for SARS-CoV-2, being subject to home isolation and being infected with SARS-CoV-2. Those who were tested for SARS-CoV-2 had a higher sense of uncertainty in workplace, by 1,422 points on average (Table 6). SARS-CoV-2 virus infection increased negative feelings about social relations at work, while staying in social isolation decreased them (Table 7). Those who had SARS-CoV-2 infection had, 0.575 points higher feelings of threat at work on average than those who did not have the infection (Table 8).

3.4.2 Factors affecting the GHQ-28 total health score

Using regression analysis, a model was developed to describe the impact on the overall measure of mental health according to the GHQ-28 of socio-professional factors (age, years of work, education, work system) and factors related to the COVID-19 pandemic.

TABLE 4 Undergoing SARS-CoV-2 virus testing vs. subjective evaluation of job characteristics.

Subjective evaluation of work	SARS-CoV-2 test performed						*p*
	Yes (*N* = 691)			No (*N* = 105)			
	$\bar{x}$	Me	*s*	$\bar{x}$	Me	*s*	
General stress	118.0	110	35.3	111.1	103	32.7	0.0410*
Work overload	19.4	18	6.9	18.5	18	6.5	0.3008
Lack of rewards	16.4	15	6.7	15.5	14	6.7	0.1358
Uncertainty in workplace	16.4	16	5.6	14.9	14	5.3	0.0048**
Social relations	10.6	-	3.3	10.3	-	3.3	0.4142
Threat	12.0	11	3.8	11.2	11	3.6	0.0391*
Physical burdens	8.1	8	4.8	7.4	8	4.0	0.3139
Unpleasant working conditions	5.3	3	3.2	4.7	3	3.0	0.0649
Lack of control	8.7	8	2.8	8.7	8	2.6	0.4580
Lack of support	5.4	5	2.4	5.2	5	2.2	0.6186
Responsibility	9.3	-	3.0	8.7	8	3.1	0.0121*

TABLE 5 Undergoing SARS-CoV-2 virus testing vs. self-rated mental health.

GHQ-28	SARS-CoV-2 test performed						*p*
	Yes (*N* = 691)			No (*N* = 105)			
	$\bar{x}$	Me	*s*	$\bar{x}$	Me	*s*	
Somatic symptoms	2.10	1	2.20	1.69	1	2.20	0.0334*
Anxiety/insomnia	1.94	1	2.25	1.40	0	2.04	0.0056**
Social dysfunction	1.14	0	1.84	0.99	0	1.76	0.5272
Severe depression	0.39	0	1.15	0.29	0	1.01	0.3676
Total score	5.58	3	6.25	4.36	2	5.90	0.0226*

TABLE 6 The impact of socio-occupational factors and those resulting from the COVID-19 pandemic on perceptions of uncertainty in workplace.

Independent factors	Uncertainty in workplace R^2 = 2.2% F = 5.9 p = 0.0005***		
	B (95% c.i.)	*p*	ß
SARS-CoV-2 test	1.422 (0.268; 2.576)	0.0158*	0.09
Years of work	0.051 (0.010; 0.092)	0.0158*	0.09
Work system (12 vs. 8 h)	0.866 (−0.028; 1.761)	0.0577	0.07

Detailed measures from the GHQ-28 questionnaire were not subjected to regression analysis because they show excessively homogeneous distribution – most values are 0.

The model for the overall ill-being symptom score does little to explain the variation of this characteristic – the coefficient of determination is only 2.5%. The years of work trait was most strongly associated with the overall mental health score. Subjects who tested positive for SARS-CoV-2 had worse general well-being. The GHQ-28 overall measure is higher, by about 1,282 points on average (Table 9).

4 Discussion

The nurses surveyed rated their work as highly taxing. Nursing's high position in rankings of the most stressful professions confirms the validity of such an assessment (34, 35). In our survey, a substantial 62.8% of respondents categorized the perceived overall level of work-induced stress as very high. Some components of the comprehensive SWEQ questionnaire were rated as very high by an even larger proportion of participants. Social relations induced very high stress in 77.8% of the respondents, in 70.6% - by threat, and in 70.4% – by responsibility. Only unpleasant work conditions, indicated as a highly stressful factor by only 39.7% of respondents, significantly differed from the other measures. The high percentage of scores considered high may be due to the fact that the authors of the questionnaire set normal ranges by taking different occupations into account (8). This implies that nurses tend to identify a relatively higher number of negative aspects in their work in comparison to other occupations. All measures of the SWEQ questionnaire were characterized by right-handed asymmetry, meaning that more nurses surveyed described the presence of burdens at a low or average level than at a high level. Similar results were obtained in studies conducted in hospitals in other parts of the country (36, 37). In surveys of nurses from other countries, work overload was the most stressful aspect of the job. In terms of other stressful traits occurring, we have not been able to identify a significant pattern among published research findings (38–40), which is likely due to cultural differences and the use of different research tools.

Overall, the nurses rated their mental health fairly well. Most subjects did not indicate symptoms of social dysfunction or severe depression. However, the distribution of GHQ-28 mental health measures in our studies is characterized by high asymmetry. The values of the GHQ-28 measures had right-sided asymmetric distributions, in particular, a very high asymmetry index appeared for symptoms of depression. This means that for most people, the level of health complaints was low (and, indeed, the median score was 0 for dysfunction and depression, meaning at least half of the respondents had no complaints in terms of this aspect). Somatic symptoms were the most frequent, while severe depression was the least frequent. With regard to this, our results differ from that obtained in a study conducted in Iran (41), where the most common disorder was social dysfunction by far, with somatic symptoms only in third place. Moreover, according to Greek researchers, depressive conditions were far more common than in our country, and anxiety/insomnia were reported on a similar level (42). Studies conducted in other regions of Poland and Lithuania reported results similar to ours (43, 44).

The COVID-19 pandemic has had a huge impact on the lives of entire societies, and in particular on the operation of health services.

TABLE 7 The impact of socio-occupational factors and those resulting from the COVID-19 pandemic on social relations.

Independent factors	Social relations R^2 = 3.2% F = 6.3 p = 0.0001***		
	B (95% c.i.)	*p*	*ß*
Staying in home isolation	−0.506 (−1.037; 0.026)	0.0621	−0.08
SARS-CoV-2 virus infection	0.694 (0.165; 1.223)	0.0102*	0.11
Years of work	0.036 (0.012; 0.060)	0.0035**	0.10
Work system (12 vs. 8 h)	0.735 (0.216; 1.254)	0.0056**	0.10

TABLE 8 The impact of socio-occupational factors and those resulting from the COVID-19 pandemic on feelings of threat.

Independent factors	Threat R^2 = 2.6% F = 5.2 p = 0.0004***		
	B (95% c.i.)	*p*	*ß*
SARS-CoV-2 virus infection	0.574 (0.040; 1.107)	0.0350*	0.07
Age	−0.061 (−0.105; −0.017)	0.0063**	−0.19
Years of work	0.087 (0.032; 0.142)	0.0020**	0.21
Work system (12 vs. 8 h)	0.683 (0.067; 1.298)	0.0298*	0.08

TABLE 9 The impact of socio-occupational factors and those resulting from the COVID-19 pandemic on the overall mental health assessment score.

Independent factors	General results R^2 = 2.5% F = 6.5 p = 0.0002***		
	B (95% c.i.)	*p*	*ß*
SARS-CoV-2 test	1.282 (0.001; 2.563)	0.0499*	0.07
Years of work	0.085 (0.039; 0.131)	0.0003***	0.13

The issue has been extensively studied, and there has been a negative impact in most cases (29, 30, 35). Still, upon comparing the present results to our results conducted before the COVID-19 pandemic was announced, we found no significant differences in the subjective assessment of job characteristics (SWEQ) or the nurses' self-assessment of mental health (GHQ-28). Both studies were conducted on a similar group of nurses working in hospitals in the Podlaskie region (45).

In the subsequent step of the analysis, we compared how selected pandemic-related elements, i.e., direct contact with a patient infected with SARS-CoV-2, staying in quarantine, home isolation, being tested for the virus and being infected with SARS-Cov-2 itself, are correlated with subjective assessment of workplace burdens and self-assessment of mental health in groups of nurses who were directly exposed to these factors or not. Overall, it can be said that the differences between the groups are small. For the subjective assessment of work characteristics, we found no correlation of most pandemic factors with the occurrence of individual workloads. Undergoing virus testing was the only factor worth noting. Nurses tested experienced higher levels of general stress, uncertainty in the workplace, a sense of threat and discomfort in the area of feeling responsible.

Being tested for the virus was also the only factor that differentiated the groups in terms of self-rated mental health. Nurses subjected to Sars-CoV-2 virus testing demonstrated a 38.6% heightened intensity in anxiety and insomnia, alongside a 24.2% increased severity in somatic symptoms compared to their non-tested counterparts. Moreover, the overall GHQ-28 score among tested nurses registered a 30.0% reduction compared to those who did not undergo testing. It can be concluded that testing had a poor effect on nurses' working conditions, as it introduced additional nervousness. Genetic tests were the ones performed during the study period, and their result was known only after several or over a dozen hours. One can safely surmise that the anticipation of the test result and the accompanying fear of being infected, was the most stressful factor, rather than the test itself. Similar results were obtained by researchers in China (30), where nurses were also most concerned about whether they were infected and whether they could transmit the virus to others. Other researchers confirm the effect of factors related to the COVID-19 pandemic as stressors, but also fail to show their direct effect on subjective feelings of stress and mental health of health workers (46, 47).

Using regression models, we studied how demographic and occupational factors, as well as factors related to the COVID-19 pandemic, might affect the subjective assessment of job characteristics according to the SWEQ questionnaire, and nurses' mental health assessment with the GHQ-28 summary measure. Amid the factors linked to the COVID-19 pandemic, the process of undergoing SARS-CoV-2 virus testing was linked to a 1.422-point increase in feelings of uncertainty within the workplace, accompanied by a 1.282-point decline in self-rated mental health. This confirms the results obtained in the correlation analysis and is consistent with the results reported by other researchers, according to which intensive testing of nurses a significantly stressful factor is (48–50). This raises the question: has intensive testing of nurses, especially asymptomatic nurses, done more harm to the mental health of workers than good, in terms of controlling the pandemic spread? Perhaps it would be worthwhile to order testing with greater caution in general in the case of future outbreaks.

Virus infection yielded a 0.574-point augmentation in perceived threat and a 0.694-point reduction in social interaction. The interpretation of this result seems fairly obvious (51). An infected individual usually feels a threat to their health or even life, and as an emitter of the "pestilence," experiences stress about whether they have spread the virus to their loved ones or co-workers, or experiences grudge with regard to those who potentially infected them, especially during the COVID-19 pandemic, where the media constantly broadcast information spreading the fear of havoc wrought by the virus.

Two factors associated with the COVID-19 pandemic surprisingly reduced some of the psychosocial burden on nurses in the workplace. Home isolation was associated with a 0.506-point enhancement in social interaction. Paradoxically, in this day and age, when a significant portion of human contact has been digitized through the proliferation of social media and video platforms, being in seclusion allows for intensification of social contacts (52). Interactions with an infected patient were linked to a 0.499-point decrease in work-related discomfort attributed to a perceived lack of control. This phenomenon is difficult to explain logically.

We did not find any effect of age and education level on the evaluation of work characteristics or mental health. There were relationships found with regard to years of work experience and the work system. Employees with greater tenure demonstrated heightened perceptions of lack of rewards, increased workplace uncertainty, altered social relations, heightened sense of threat, lack of support, heightened responsibility, and elevated general stress levels. Additionally, nurses on 12-h shifts reported amplified psychological strain, increased perception of insufficient rewards, altered social relations, heightened sense of threat, heightened physical burdens, unpleased working conditions, lack of control, elevated sense of responsibility, and increased general stress compared to their counterparts on 8-h shifts. Notably, in the context of self-assessed mental health, we observed a statistically significant relationship solely between extended work experience and poorer health ratings. The findings obtained appear to align closely with established trends documented in previous research (25, 30). Working on a 12-h system is more taxing in all respects, both physically and mentally. In the case of seniority, some studies confirm greater resilience to workplace stress, and others (as in our case) just the opposite (53, 54). The low statistical strength of the obtained correlations is noteworthy, not only in terms of our study (55). This shows that the feeling of strain at the workplace is a very complex process that depends on a great number of factors in an individualized way, and also depends on numerous conditions that are extremely difficult to list.

The COVID-19 pandemic's impact on healthcare services has been widely studied (56, 57), yet our recent analysis, compared with pre-pandemic data, revealed no significant changes in nurses' perceptions of job characteristics or self-assessed mental health. Notably, virus testing emerged as a significant stressor, associated with heightened stress levels and feelings of organizational threat. Infection was linked to increased perceived threat and decreased social interaction, reflecting the psychological strain and fear amid media coverage. Counterintuitively, home isolation exhibited a marginal enhancement in social relationships, while contact with infected patients yielded a slight alleviation of discomfort related to the perceived lack of control, which was not reflected in the results of other researchers. These findings underscore the complexities of pandemic-related stressors and highlight the need for targeted

interventions and support strategies for healthcare workers in future crises.

5 Conclusion

1 The COVID-19 pandemic did not change nurses' subjective perceptions of job characteristics, nor did it change their self-assessment of mental health.
2 The impact of factors stemming from the COVID-19 pandemic, including exposure to infected patients, quarantine or home isolation, and even SARS-CoV-2 virus infection, did not significantly influence nurses' self-assessment of their mental well-being.
3 In the event of future pandemics, managers should reconsider the need to intensively test nurses for the SARS-CoV-2 virus, as testing has been a factor in intensifying nurses' feelings of negativity about their work and worsening their self-assessment of their mental health.

6 Methodological limitations

The utilization of a limited sample, adoption of a cross-sectional study design, and reliance on self-reported questionnaires represent noteworthy constraints of this investigation. Notably, the study was confined to two hospitals situated within a single region of Poland. Furthermore, the specific reasons underlying the non-participation of 30.4% of the invited individuals remain undetermined, primarily attributable to the procedural nature of the study. It is essential to emphasize that prior and contemporaneous studies involving analogous cohorts of nurses were executed, albeit not among identical participant groups, both preceding and during the COVID-19 pandemic.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Bioethical Committee. Medical University of Bialystok, Bialystok, Poland. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KK: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. KT: Conceptualization, Validation, Writing – review & editing. JC: Investigation, Validation, Writing – review & editing. EK-K: Methodology, Writing – review & editing. MS: Data curation, Software, Writing – original draft, Writing – review & editing. JH: Formal analysis, Methodology, Writing – review & editing.

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The positive effects of positive coping on mental health in college students during the COVID-19 campus lockdown

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Objectives: Isolation has been an effective method to control the spread of COVID-19 over the past 3 years. However, lifestyle changes may have a negative impact on mental health. To examine the effects of positive coping on mental health in college students during the COVID-19 campus lockdown, this study conducted an online cross-sectional survey.

Methods: In October 2022, following a prolonged campus lockdown of nearly 3 years, 313 university students from a university in Shandong Province, China, were invited to complete an online questionnaire. The questionnaire comprised a self-administered general situation questionnaire, the Simple Coping Style Scale, and the Hospital Depression and Anxiety Scale.

Results: (1) The analysis of variance revealed a significant main effect of coping Style on depression [$F(4,300) = 2.446$, $p = 0.047$] during the COVID-19 campus lockdown. A *post-hoc* test indicated that college students who engaged in study ($p = 0.012$) or sports ($p = 0.027$) during their free time had significantly lower depression scores than those who used the Internet. (2) Independent sample t-tests showed significant differences in positive and negative coping styles among college students in terms of depression ($t = 6.891$, $p < 0.001$) and anxiety scores ($t = 7.745$, $p < 0.001$). (3) Pearson correlation analysis demonstrated a negative correlation between positive coping style and anxiety ($r = -0.378$, $p < 0.001$), and between positive coping style and depression ($r = 0.427$, $p < 0.001$). Positive correlations were also found between the negative coping style and anxiety ($r = 0.155$, $p = 0.007$), and between the negative coping style and depression ($r = 0.190$, $p < 0.001$).

Discussion: The study suggested that fostering positive coping in students can mitigate mental health issues during crises, providing a blueprint for university mental health initiatives during epidemics.

KEYWORDS

COVID-19, campus lockdown, coping style, mental health, crisis

Introduction

The COVID-19, as a public health emergency, has had extensive and lasting effects on people's mental health, especially for the college students who were locked up on campus for a long time. After the outbreak of COVID-19, some studies have found that the proportion of depression and anxiety among college students was very high (1, 2). Some studies have even found that 51 and 45.9% of students have anxiety and depression, respectively (3). Fortunately, studies have found positive mental health variables in alleviating symptoms

of psychological distress such as depression and anxiety among college students during COVID-19. Biber et al. (4) explored data from college students during COVID-19 and found that more optimism and gratitude are closely related to lower anxiety (4). Research by Michelle Haikalis et al. suggests that subjects who perceive greater positive changes brought about by COVID-19 have alleviated increases in anxiety and depression (5). Research by Seyedmohammad Mirhosseini et al. found that life satisfaction is a protective factor in preventing depression during the pandemic (6). It suggested that positive coping strategies such as engaging in more positive activities or taking a more positive perspective on situations might reduce the damage to the mental health.

Coping has been identified as a crucial factor influencing individuals' mental health amidst the COVID-19 pandemic (7, 8). It is characterized by a relatively stable yet dynamic style or feature that adapts to various circumstances. In critical situations, effective coping strategies can serve as protective factors against mental health issues. It's noteworthy that individuals employing specific coping styles exhibit varying mental health outcomes. Coping styles can be broadly classified into positive and negative (9, 10). Research indicates that negative coping styles are linked with mental health problems, whereas method-oriented coping strategies are associated with improved mental health compared to avoidance coping strategies (11–14). College students may respond to the pandemic through activities such as exercise, internet usage, or studying. Exercise has been positively correlated with positive coping styles. Regular exercisers tend to employ positive coping styles more frequently, potentially reducing anxiety levels (15). Conversely, adolescents spending extensive time online have been found to be more prone to depression (16). However, dedicating more leisure time to studying can alleviate academic stress, subsequently reducing depressive symptoms (17–20). Studies have demonstrated that positive problem responses in community samples are associated with lower depression levels, while negative responses correlate with higher depression levels (21, 22).

As a result of COVID-19, people's mental health is significantly affected (23), and individual coping styles can buffer the effects of the external environment on mental health (24). College students, as the most mobile and active group of students, are not yet fully mature in ideology and psychology. Consequently, they are severely affected. However, during the COVID-19 pandemic, a significant crisis event, it remains uncertain whether the individual coping styles of college students confined to campus have a significant positive or negative impact on depression and anxiety levels. Answering this question will enable us to implement appropriate measures to assist college students in maintaining their mental health during such incidents. Therefore, to understand whether coping styles and what coping strategies having an impact on depression and anxiety status of college students during the COVID-19 campus closure, this study recruited 313 college students who were incarcerated in schools and explored the relationship between coping and depression and anxiety during the period of epidemic interdiction.

We proposed three hypotheses. First, as the duration of COVID-19 increases, the depression and anxiety levels of college students should decrease compared to the initial few months of COVID-19. Second, we hypothesized that during COVID-19, college students who adopted positive coping styles such as studying or exercising would exhibit lower depression and anxiety scores. In contrast, those who adopted negative coping styles such as internet surfing would exhibit higher depression or anxiety scores. Third, we also hypothesized a significant association between college students' coping styles and depression and anxiety levels. We expected a negative correlation between positive coping style and depression or anxiety level, and a positive correlation between negative coping styles and depression or anxiety levels.

Materials and methods

The data of this project were collected from a university in China (Shandong Normal University). After a long time campus lockdown (nearly 3 years), a total of 313 questionnaires were distributed. After excluding a few participants who filled out the questionnaire incorrectly due to carelessness, finally 305 valid questionnaires were collected, resulting in an effective rate of 97.44%. The participants' ages ranged from 18 to 26 years, with an average age of 20.05 ± 0.91 years. The sample included 116 males and 189 females. Data was collected via an online platform named "wjx" by the end of October 2022. Online informed consent was obtained from all participants prior to completing the online questionnaires. The study was approved by the local ethical committee of School of Psychology, Shandong Normal University and all research activities were adhered to the principles of the Declaration of Helsinki.

Measures

General questionnaire

On the "wjx" platform, we developed a general questionnaire covering gender, age, exercise, study, Internet access, and other ways of coping, as well as the impact of COVID-19 on certain inconveniences.

Simple coping style scale

A simplified coping style questionnaire (SCSQ) was used to investigate individual coping style tendencies. This scale was developed based on a comprehensive understanding of coping styles at home and abroad in conjunction with the characteristics of China's population. It has good reliability and validity among Chinese college students, with a Cronbach's alpha coefficient of 0.9 (10). There were 20 items in total, including two dimensions of positive and negative coping. The dimension of positive coping was composed of items 1–12, which mainly reflected the characteristics of positive coping. The dimension of negative coping was composed of items 13–20, which mainly reflected the characteristics of negative coping. In the questionnaire, a four-level scale ranging from 0 to 3 was used. The higher the positive coping score, the more inclined the respondents are to adopt positive coping styles. The higher the negative coping score, the more likely the respondents were to adopt negative coping styles. The Cronbach's α for this scale in this study was 0.852.

Hospital depression and anxiety scale

In order to assess individual depression and anxiety, the Hospital Anxiety and Depression Scale (HADS) was utilized. According to Zigmond and Snaith (25), the scale was universal and consisted of 14 items, seven of which were related to depression, and seven to anxiety. In the Chinese population, the scale also has good reliability and validity 24 with a Cronbach'sα coefficient of 0.879 (26). There were four options available for each item, marked by "0 ", "1 ", "2 ", and "3 ". The anxiety and depression items crossed, and their total scores were calculated by overlaying the two sets of items. A higher score indicates that the subjects are suffering from depression or anxiety to a greater extent. The Cronbach's α for this scale in this study was 0.854.

Statistical analysis

Data analysis was conducted using SPSS version 22.0. The independent samples *t*-test was used to compare means between two groups, while one-way ANOVA was employed to compare means among multiple groups. Pearson correlation analysis was utilized for correlation analysis. All statistical tests in this study were conducted at a significance level of $p < 0.05$.

Results

A general profile of study participants

The survey revealed that the majority of students ($n = 191$ or 62.6%) spent their free time surfing the Internet during the COVID-19 campus lockdown. This was followed by studying (47 students, 15.4%), chatting with classmates (31 students, 10.2%), exercising (28 students, 9.2%), and other ways (8 students, 2.6%). According to the survey, 135 students (44.3%) believed that COVID-19 had a significant impact on going home from school and going out to play, while 103 students (33.8%) thought it had a very significant impact. For details, see Table 1.

TABLE 1 General information ($N = 305$).

		Number of people	Composition ratio (%)
How to spend free time during the COVID-19	Study	47	15.4
	Internet surfing	191	62.6
	Exercise	28	9.2
	Chatting with classmates	31	10.2
	Others	8	2.6
How much of an effect on going home from school and going out to play	No reduction in frequency	4	1.3
	No impact	28	9.2
	Basically no impact	35	11.5
	Had some impact	135	44.3
	Had a significant impact	103	33.8

The results measured by the HADS

The results indicated that 21% of college students ($n = 64$) scored 8 or more on the anxiety scale, while 15.4% of college students ($n = 47$) scored 8 or more on the depression scale. This suggests that 15.4% of college students may be experiencing depression and 21.0% may be dealing with anxiety. The detection rates of depression and anxiety in this study are lower than they were in the initial few months of the pandemic (30.7 and 23.9%, respectively) (2), which supports the first hypothesis.

Depression and anxiety scores with different coping styles during the COVID-19 campus lockdown

In this study, studying and exercising are considered positive coping strategies, while surfing the Internet and chatting are considered negative strategies. A one-way ANOVA was used to evaluate the differences in depression and anxiety scores among college students who spent their free time in different ways during the COVID-19 campus lockdown. There was a significant difference in depression scores [$F(4,300) = 2.446$, $p = 0.047$] and a non-significant difference in anxiety scores [$F(4,300) = 0.817$, $p = 0.515$] among college students who spent their free time in different ways during the lockdown. Pairwise comparisons showed significant differences in depression scores between studying and surfing the Internet ($p = 0.012$), with students who spent their free time studying having significantly lower depression scores than those who spent their free time surfing the Internet. There were also significant differences between surfing the Internet and exercising ($p = 0.027$), with students who spent their free time surfing the Internet having significantly higher depression scores than those who spent their free time exercising. For details, see Table 2 and Figure 1.

To compare the depression and anxiety scores of students who tend to use positive coping with those who tend to use negative coping, independent sample t-tests were performed. It was found that students who used negative coping styles scored significantly higher in depression and anxiety than students who used positive coping styles ($t = 7.745$, $p < 0.001$; $t = 6.891$, $p < 0.001$; see Table 3 and Figure 2). These findings support the second hypothesis.

Correlation analysis

The Pearson correlation was used to analyze the correlation between coping styles and mental health status. The results revealed a negative correlation between positive coping style and anxiety ($r = -0.378$, $p < 0.001$), as well as between positive coping style and depression ($r = -0.427$, $p < 0.001$). Positive correlations were also found between negative coping

TABLE 2 ANOVA analysis of different coping styles on depression and anxiety scores.

	Study ($n = 47$)	Surf the NET ($n = 191$)	Do sports ($n = 28$)	Chat with classmate ($n = 31$)	Other ($n = 8$)	F (4,300)	p
Depression	3.40 ± 2.45	4.63 ± 2.98	3.29 ± 3.09	4.16 ± 3.71	4.25 ± 3.01	2.446*	0.047
Anxiety	4.57 ± 3.20	5.19 ± 3.27	4.46 ± 3.35	4.65 ± 3.20	6.00 ± 4.78	0.817	0.515

*$p < 0.05$.

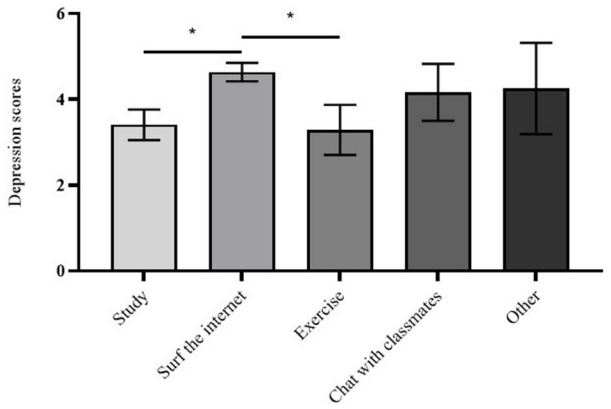

FIGURE 1
Differences in Depression Scores among Different Coping Ways during the COVID-19 campus lockdown. *$p < 0.05$. Error bars represent SE.

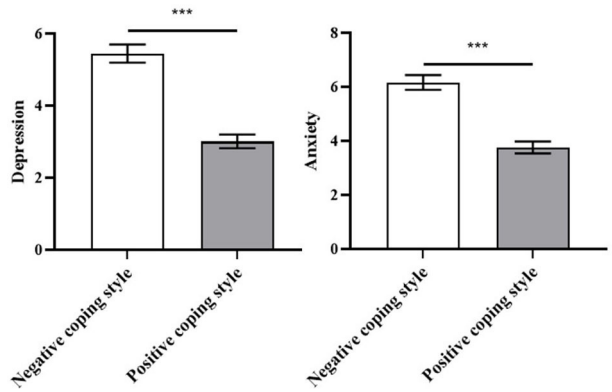

FIGURE 2
Comparison of differences in depression and anxiety scores between two coping style tendencies. ***$p < 0.001$. Error bars represent SE.

TABLE 3 T-tests for two coping style tendencies on depression and anxiety scores.

	Positive coping style ($n = 148$)	Negative coping style ($n = 157$)	t	p
Depression	3.01 ± 2.29	5.45 ± 3.16	7.745***	0.000
Anxiety	3.76 ± 2.65	6.17 ± 3.43	6.891***	0.000

***$p < 0.001$.

TABLE 4 Correlation between depression, anxiety and coping style.

	Anxiety	Depression	Positive cope	Negative cope
Anxiety	1			
Depression	0.663***	1		
Positive cope	−0.378***	−0.427***	1	
Negative cope	0.155**	0.190***	0.208***	1

**$p < 0.01$; ***$p < 0.001$.

style and anxiety ($r = 0.155$, $p = 0.007$), and between negative coping style and depression ($r = 0.190$, $p < 0.001$). Please refer to Table 4 for more details. These findings support the third hypothesis.

Discussion

During the campus lockdown period, this study utilized the Simple Coping Style Scale (SCSQ) and the Hospital Depression and Anxiety Scale (HADS) to conduct an online survey assessing the impact of coping styles on the mental health of college students. The result showed that the detection rate of anxiety and depression among college students were 21.0 and 15.4%, respectively. These rates were lower than those at the first few months of the pandemic (30.7 and 23.9%) (2). This decrease suggests that state-imposed controls and blockades on the COVID-19 pandemic were effective, and that mental health may gradually recover during later stages of a public health disaster (27). Moreover, as COVID-19 has mutated several times and risks have gradually reduced, people have adapted to the epidemic environment. This adaptation, along with initial infectious disease control measures, may improve young people's mental health (28). In addition, various psychological protective factors such as positive coping and psychological resilience might contribute to the gradual recovery of mental health (4–6).

This study found that students with negative coping styles had higher depression and anxiety scores than those with positive coping styles. Positive coping styles were significantly negatively correlated with depression and anxiety levels, while negative coping styles were significantly positively correlated with these levels. This is consistent with previous studies (29, 30), indicating that positive coping styles continue to have a protective effect on college students' mental states during the COVID-19 campus lockdown. This study found that students with negative coping styles had higher depression and anxiety scores than those with positive

coping styles. There was a significant correlation between coping style scores and depression and anxiety scores. Positive coping styles were significantly negatively correlated with depression and anxiety levels, while negative coping styles were significantly positively correlated with these levels. This is consistent with previous studies, indicating that positive coping styles continue to have a protective effect on college students' mental states during the COVID-19 campus lockdown (31). According to the theory of social cognitive stress, adopting a positive coping style may reduce an individual's negative emotions, while adopting a negative coping style may exacerbate an individual's negative emotions and reduce their subjective well-being (32, 33). Our results support this theory. Therefore, methods such as cognitive-behavioral interventions aimed at improving an individual's positive coping ability may be crucial for maintaining mental health in various stressful events. This study also investigated whether specific coping methods impact mental health during the pandemic. We examined the relationship between certain positive and negative coping methods and mental health. The results indicated that students who spent their free time on the Internet (often viewed negatively) during campus lockdown had significantly higher depression scores than those who spent their free time studying and exercising (often viewed positively). A particular syndrome, known as "headline stress disorder," is characterized by anxiety due to continuous news media coverage (34). During campus lockdowns, students could not leave school, making the Internet the most accessible means of connecting with the outside world. Consequently, they were more likely to encounter numerous epidemic reports online, including rumors. Some students struggled to discern the truth of this information, leading to increased anxiety and depression (35). Academic engagement describes the level of commitment students have toward their learning activities, which significantly influences their academic performance (36–38). Self-efficacy refers to an individual's belief in their ability to accomplish specific tasks (39). Academic self-efficacy is the belief in one's capability to handle various learning tasks (40). There is a strong positive correlation between academic self-efficacy and academic engagement, which may be mutually reinforcing (41). When students spend their free time studying, it is likely that their academic engagement increases and their academic self-efficacy improves. Higher self-efficacy is associated with lower depression levels; thus, students with higher academic self-efficacy tend to have lower depression levels (42). Studies have shown that exercise interventions positively impact psychological disorders such as anxiety and depression in college students (43–45). Therefore, students who choose positive coping methods like studying or exercising during their free time might experience lower levels of depressive mood. This finding underscored the importance of effective management of students' leisure time during campus closures. Schools could organize or guide students to engage in positive extracurricular activities to maintain a healthier psychological state.

In conclusion, our research suggested that enhancing positive coping styles among college students may reduce their susceptibility to psychological issues during crises. Specifically, our study offered coping strategies for university students: by dedicating more of their free time to learning and physical activities, students could mitigate stress during such unique crisis events. However, this study has two limitations. Firstly, all participants were undergraduates from a Normal University, which may not provide a sufficiently random and representative sample. Secondly, this study was cross-sectional. The survey was conducted at the end of October 2022, during the ongoing development of the COVID-19 pandemic. This dynamic process means that the coping styles, depression, and anxiety of college students at different stages of the pandemic's progression were not comprehensively explored.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Local Ethical Committee of School of Psychology, Shandong Normal University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

ML: Data curation, Visualization, Writing – original draft. LC: Resources, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Is the COVID-19 epidemic affecting the body mass of Chinese teenagers? – A longitudinal follow-up study

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Background: After the spread and outbreak of COVID-19 worldwide, the learning, lifestyle, and health level of young individuals have been immensely impacted. With regard to the existing studies, the development trend of adolescents' body shape in the late COVID-19 period is not sufficiently analyzed, and relevant targeted investigation is lacking. This study aimed to explore the body mass index (BMI) changes of 6–14 years-old adolescents before and after the COVID-19 epidemic, and to provide a reference for promoting the continuous enhancement of adolescent health.

Methods: The BMI and related data pertaining to 93,046 individuals from 2019 to 2022 were collected by cluster sampling, and changes in the BMI *Z* score and detection rate of overweight and obese adolescents before and after the epidemic were analyzed. Furthermore, the trend of obesity rates among adolescents in Jinan from 2019 to 2022 was analyzed using a logistic regression analysis model.

Results: The one-way ANOVA models indicated that the BMI *Z* score of 6–14 years-old adolescents in 2020 significantly increased compared to 2019 ($p < 0.01$), and decreased in 2021 and 2022; in 2020, the obesity rate of adolescents exhibited a significant increase; however, the rate decreased after being controlled in 2021 and 2022. The normal-body size proportion continued to rise ($p < 0.01$), and adolescents of different age groups and genders exhibited similar development trends; the results of the logistic regression analysis indicate that there was a significant increase in obesity rates in 2020, adolescents of different age groups and genders exhibited similar development trends ($p < 0.05$).

Conclusion: This study demonstrated that the COVID-19 epidemic impacts the BMI and obesity detection rate of adolescents. Adolescents from different age groups and genders exhibited similar development trends.

KEYWORDS

body mass index, COVID-19, physical health, adolescents, follow-up study

Highlights

– In 2020, there was a significant increase in BMI Z scores and obesity rates among adolescents; however, they were controlled and decreased in 2021 and 2022.
– Adolescents from different age groups and genders exhibited similar development trends.

Introduction

During the end of 2019, the corona virus (COVID-19) emerged and spread in China. Due to the spread of the epidemic, researchers are anticipating a major worldwide health event in 2020 (1). COVID-19 is characterized by uncertainty of variation, complexity of prevention and control, and rapid spread (2), which crucially threaten the physical and mental health of the individuals and the normal development of the social economy (3). Based on the growing problem of overweight adolescents and obesity among adolescents, more than 50% of adult residents in China are overweight and obese; similarly, nearly 20% of adolescents are overweight and obese (4). Specifically, to control the spread of COVID-19, according to the government's recommendations, Chinese residents choose home isolation and protection, and schools opt for online teaching. The reduction of outdoor activities and the increased sitting time among teenagers during home isolation may lead to adverse health effects, such as weight gain and declined physical and mental health levels (5). Therefore, to maintain optimal health, weight monitoring is crucial for adolescents.

During the adolescence stage, which is a critical period during which children transform into adults, their physical and mental development matures (6). The self-consciousness of adolescents increases with age, their emotional stability becomes poor, and their physical and mental health becomes vulnerable to the spread of the COVID-19 (7). COVID-19 has exerted an immense impact on the body shape and dietary habits of adolescents. Studies have indicated that the epidemic significantly impacts the detection rate of overweight and obese adolescents, and the poor dietary proportion (8, 9). Some research has observed that during the COVID-19 epidemic, weight, carbohydrate intake and drinking among adolescents have shown an upward trend (10–12). The body mass index (BMI), a universally accepted health marker, is widely utilized to measure malnutrition, determine whether individuals are overweight, and measure obesity (13–15). However, current research on the development trend of Chinese adolescents' body shape before and after the COVID-19 epidemic is unclear, and a lack of relevant targeted investigation is apparent.

This study aimed to analyze changes in the physical shape and health level of Chinese adolescents before and after the outbreak of COVID-19. We hypothesized that the COVID-19 epidemic significantly affects the health level of adolescents' body shape in China.

Materials and methods

Subjects

The data were collected from a national survey on physical fitness conducted among primary and junior schools between 2019 and 2022 in Jinan, Shandong province, China. 6–14 years-old children completed the measurement and collection of body shape data, and judged various categories such as low weight, normal, overweight and obesity according to the Chinese national standards "Screening for Malnutrition in School Age Children and Adolescents (WS/T 456-2014)" and "Screening for Overweight and Obesity in School Age Children and Adolescents (WS/T 586-2018)." For all participants, both participants and their parents (or guardians) provided their informed consent. The study protocol complied with the Declaration of Helsinki and was approved by the Ethics Committee of Shandong Normal University (2021036).

Procedures

Based on the technical specifications including the "National Student Physical Health Standard," we conducted anthropometric measurements. We adopted intelligent physical health monitoring equipment, such as a height tester (GMCS-SGJ3) and weight tester (GMCS-RCS3), and we utilized non-contact measurement using the infrared multi-point sensor array, which automatically recorded the students' data and uploaded these values to the system for storage.

Height and weight

In the process of measuring the height and weight indicators of teenagers, students are required to take off their shoes and hats, and to stand on the bottom plate of the measuring instrument with their backs facing the pillar, their torso naturally straight, and their eyes facing forward. The upper limbs naturally droop, and the legs straighten. The students are required to keep the heels together, their toes approximately 60° apart, and their heels, sacrum, and scapula in contact with the column; thus, they can maintain the standing posture of "three points and one line," with the unit of cm and kg. The accuracy is set at 1 decimal place (16). The height and weight data of teenagers have been measured only once, and calculate the incidence rate of overweight and obesity among adolescents.

BMI calculation

The BMI was calculated using the following formula: BMI = weight (kg)/height (m)^2. Students were divided into four categories based on their BMI values according to the World Health Organization (WHO) criteria, namely <18.5 kg/m^2, 18.5–23.9 kg/m^2, 24–27.9 kg/m^2, and ≥28 kg/m^2, which represent underweight, average weight, overweight, and obese individuals, respectively (17). According to the WHO growth curve for children and adolescents of different ages and genders (18), the BMI Z score for each participant was calculated using the following formula: BMI Z score = (measurement

value − median of the same age and gender reference standard)/ standard deviation of the reference standard (19). A >1 BMI *Z* score indicates that adolescents are overweight; a >2 BMI *Z* score indicates obesity in adolescents; and a <−2 BMI *Z* score indicates weight loss in adolescents (20).

Calculation

Statistical analysis

Experimental data were processed using the IBM SPSS statistical software (version 26.0, Chicago, IL, United States). All data were presented as "mean ± standard deviation" (M ± SD). An independent sample *t*-test, *z*-test or one-way analysis of variance (ANOVA) was conducted to compare the mean differences among groups. The logistic regression analysis model was utilized to determine the trends in the body shape compliance rate throughout the study duration, and the significance level was set at $p < 0.05$ for all tests.

Results

Descriptive analysis

This study included a total of 93,046 adolescents aged 6–14 in Jinan City from 2019 to 2022. 21,966, 23,049, 23,607, and 24,424 individuals were collected from 2019 to 2022, including 48,790 males (52.44%) and 44,256 females (47.56%). In the data samples collected from 2019 to 2022, there was no statistically significant difference in age between adolescent boys and girls ($p > 0.05$), and boys exhibited higher height, weight, BMI, and BMI *Z* scores than girls ($p < 0.01$). (height in 2019, 2020, 2021, 2022)[boys: 150.60 ± 17.98 cm, 151.09 ± 17.82 cm, 151.51 ± 18.25 cm, 150.54 ± 18.52 cm; girls: 147.57 ± 15.45 cm, 148.20 ± 15.66 cm, 148.35 ± 15.86 cm, 147.79 ± 16.23 cm]; (weight in 2019, 2020, 2021, 2022)[boys: 48.27 ± 19.51 kg, 49.01 ± 20.14 kg, 48.67 ± 20.14 kg, 47.62 ± 19.69 kg; girls: 43.20 ± 15.50 kg, 43.52 ± 16.04 kg, 43.44 ± 16.13 kg, 42.81 ± 15.97 kg]; (BMI *Z* scores in 2019, 2020, 2021, 2022)[boys: 0.78 ± 0.98, 0.80 ± 0.99, 0.74 ± 0.95, 0.73 ± 1.05; girls: 0.36 ± 0.69, 0.39 ± 0.70, 0.35 ± 0.69, 0.34 ± 0.76].

In 2020, the BMI *Z* score of 6–14 years-old adolescents in Jinan City significantly increased compared to 2019 and was higher than the maximum values in 2019, 2021, and 2022 (2019: 0.56 ± 0.88; 2020: 0.63 ± 0.89; 2021: 0.56 ± 0.86; 2022: 0.54 ± 0.94; $F = 18.354$, $p < 0.01$). The BMI *Z* scores of 6–14 years-old adolescents in all age groups exhibited a similar development trend, with a significant increase in BMI *Z* scores in 2020 and a decrease in 2021 and 2022.

By comparing the low weight, normal, overweight, and obesity detection rates among adolescents in Jinan from 2019 to 2022, it is observed that with the outbreak of COVID-19, the obesity rate of adolescents in all groups increased to varying degrees in 2020, and the proportion of normal body shape declined. With the enhancement of epidemic prevention and control as well as the adaptability of adolescents, the obesity rate has been controlled and decreased in 2021 and 2022, and the proportion of normal body size has been continuously increasing (2019:62.32%; 2020: 61.01%; 2021: 62.73%; 2022: 63.57%, trend $X^2 = 44.359$, $p < 0.01$, Cramer's $V = 0.018$). Teenagers of different academic stages and genders exhibit similar development trends.

Regressive analysis

After adjusting for age, grade, and gender factors, a logistic regression analysis was conducted to investigate the changes in overweight and obesity overweight and obesity rates among boys, girls, primary school students, middle school students, and total students. The logistic regression analysis indicated that the changing trend of the adolescent obesity rate in Jinan City from 2019 to 2022 was analyzed. Using a regression analysis, it was observed that the detection rate of adolescent obesity in 2020 exhibited a significant increase compared to 2019, and decreased in 2021 and 2022, with a statistically significant change ($p < 0.05$). Moreover, the study observed a similar trend of change between boys and girls (boys: OR = 1.087, 95% CI = 1.031–1.146, $p < 0.05$; girls: OR = 0.957, 95% CI = 0.903–1.015, $p < 0.05$), as well as between primary and middle school stages (primary and middle school stage: OR = 1.103, 95% CI = 1.039–1.17, $p < 0.05$; middle-school stage: OR = 1.103, 95% CI = 1.039–1.17, $p < 0.05$). The obesity detection rate significantly increased in 2020 and decreased in 2021 and 2022.

Discussion

The study conducted the first longitudinal survey on the changes and trends in indicators (e.g., BMI and obesity rate) among Chinese adolescents before and after the COVID-19 epidemic. This study demonstrated that the BMI *Z* score and obesity rate of adolescents aged 6–14 in 2020 have significantly increased compared to 2019, and have been controlled to decrease in 2021 and 2022. The proportion of normal body size continues to increase in 2021 and 2022, and adolescents of different academic stages and genders exhibit similar development trends. The results of this study indicates that COVID-19 exerts a negative impact on the physical shape and health of young individuals. With the enhanced epidemic control and adaptability, young individuals exhibit a more healthy physical shape.

The results of this study indicates that the weight and obesity rate of adolescents increased after the COVID-19 epidemic, and the preceding conclusion is consistent with the relevant research results. Wen (21) and Jia's research (22) recruited 10,082 and 19,066 adolescents from China, respectively, and the comparison indicated that the obesity rate of adolescents increased from 10.5 to 12.6% before and after the epidemic. Another survey indicated that the obesity rate increased from 10.47 to 12.28%. Researchers from countries including Germany (23) and Greece (24) noted that during the COVID-19 epidemic, the weight of adolescents exhibited an increasing trend. According to the results, the weight and obesity rate of adolescents are exhibiting an increasing trend, similar to that described in a previous study. In the late COVID-19 period, with the enhancement of adolescents' adaptability and prevention and control level, the BMI *Z* score and obesity rate of 6-14-year-old individuals declined, and the proportion of normal sized adolescents continued to rise.

The regression analysis results indicate that the detection rate of adolescent obesity in 2020 exhibited a significant increase compared to 2019, and decreased in 2021 and 2022. Moreover, the study observed a similar trend of change between males and females, as well as between the primary and middle school stages. The aforementioned conclusion is consistent with the relevant research results. Huang's study (25) revealed that in the COVID-19 context, the weight gain risk increased with the increase in transmission time of COVID-19. During the COVID-19 epidemic, the significantly increased obesity rate of adolescents was related to the home isolation management mode. Due to the reduction of outdoor activities and the increase of sedentary time among adolescents, obesity became a more critical research topic.

However, this study exhibits some limitations. First, the study, which collected and analyzed body shape data for only primary and middle school stages, did not comprehensively consider the entire growth cycle of adolescents. Therefore, the development status of adolescents in each stage should be comprehensively considered. Second, because >95% study participants were from Jinan City, Shandong Province, the sample did not comprehensively represent the adolescents' population in China. Studies with larger sample sizes and comprising participants from different provinces, as well as other cohorts (e.g., age), are warranted to examine and confirm the observations recorded herein (see Tables 1–4).

TABLE 1 Mean and standard deviation of age, height, weight, BMI, BMI *Z* score of Adolescents in Jinan City from the years 2019 to 2022.

Years	Gender	Statistical value	Age	Height (cm)	Weight (kg)	BMI (kg m^{-2})	BMI *Z* score
2019	Male		10.22 ± 2.68	150.60 ± 17.98[a]	48.27 ± 19.51[b]	20.41 ± 4.77[c]	0.78 ± 0.98[d]
	Female		10.24 ± 2.65	147.57 ± 15.45[a]	43.20 ± 15.50[b]	19.19 ± 4.11[c]	0.36 ± 0.69[d]
		t	−0.554	13.334	21.161	20.142	35.569
		P	0.579	<0.01	<0.01	<0.01	<0.01
2020	Male		10.24 ± 2.66	151.09 ± 17.82[a]	49.01 ± 20.14[b]	20.57 ± 4.97[c]	0.80 ± 0.99[d]
	Female		10.27 ± 2.66	148.20 ± 15.66[a]	43.52 ± 16.04[b]	19.23 ± 4.20[c]	0.39 ± 0.70[d]
		t	−0.822	13.026	22.760	23.759	34.997
		P	0.411	<0.01	<0.01	<0.01	<0.01
2021	Male		10.21 ± 2.70	151.51 ± 18.25[a]	48.67 ± 20.14[b]	20.28 ± 4.80[c]	0.74 ± 0.95[d]
	Female		10.26 ± 2.68	148.35 ± 15.86[a]	43.44 ± 16.13[b]	19.05 ± 4.21[c]	0.35 ± 0.69[d]
		t	−1.608	14.138	21.883	20.969	36.288
		P	0.108	<0.01	<0.01	<0.01	<0.01
2022	Male		10.07 ± 2.69	150.54 ± 18.52[a]	47.62 ± 19.69[b]	20.12 ± 4.82[c]	0.73 ± 1.05[d]
	Female		10.12 ± 2.78	147.79 ± 16.23[a]	42.81 ± 15.97[b]	18.91 ± 4.25[c]	0.34 ± 0.76[d]
		t	−1.424	12.321	20.846	20.761	33.952
		P	0.154	<0.01	<0.01	<0.01	<0.01

[a]Significant statistical difference between boys and girls in height, $p < 0.05$.
[b]Significant statistical difference between boys and girls in weight, $p < 0.05$.
[c]Significant statistical difference between boys and girls in BMI, $p < 0.05$.
[d]Significant statistical difference between boys and girls in BMI *Z* score, $p < 0.05$.

TABLE 4 Logistic regression analysis of low weight, normal, overweight, and obesity detection among 6–14 years-old adolescents in Jinan City from 2019 to 2022.

Years	OR(95%CI)				
	Male	Female	Primary school	Middle school	Total
2019	1.000[a]	1.000[b]	1.000[c]	1.000[d]	1.000[e]
2020	1.087 (1.031–1.146)[a]	0.957 (0.903–1.015)[b]	0.972 (0.923–1.025)[c]	1.103 (1.039–1.17)[d]	1.027 (0.988–1.068)[e]
2021	0.990 (0.939–1.043)[a]	0.917 (0.865–0.972)[b]	0.887 (0.842–0.935)[c]	1.069 (1.007–1.134)[d]	0.956 (0.919–0.994)[e]
2022	0.974 (0.925–1.027)[a]	0.873 (0.824–0.926)[b]	0.917 (0.871–0.965)[c]	0.948 (0.893–1.007)[d]	0.927 (0.892–0.964)[e]
P	<0.05	<0.05	<0.05	<0.05	<0.05

[a]Significant statistical difference in 2019, 2020, 2021, and 2022 for male, $p < 0.05$.
[b]Significant statistical difference in 2019, 2020, 2021, and 2022 for female, $p < 0.05$.
[c]Significant statistical difference in 2019, 2020, 2021, and 2022 for primary school, $p < 0.05$.
[d]Significant statistical difference in 2019, 2020, 2021, and 2022 for middle school, $p < 0.05$.
[e]Significant statistical difference in 2019, 2020, 2021, and 2022 for total, $p < 0.05$.

TABLE 2 Mean and standard deviation of BMI *Z* score of Adolescents in Jinan City from the years 2019 to 2022.

Age	2019		2020		2021		2022		*F*	*P*
	n	M ± SD	*n*	M ± SD	*n*	M ± SD	*n*	M ± SD		
6	2,420	0.28 ± 0.87[a]	2,472	0.41 ± 0.91[a]	2,642	0.32 ± 0.88[a]	3,002	0.36 ± 1.39[a]	7.236	<0.01
7	2,402	0.49 ± 0.95[b]	2,422	0.58 ± 0.99[b]	2,483	0.45 ± 0.92[b]	2,652	0.46 ± 0.94[b]	9.089	<0.01
8	2,223	0.63 ± 1.01[c]	2,407	0.65 ± 1.00[c]	2,407	0.58 ± 0.99[c]	2,476	0.56 ± 0.93[c]	4.499	<0.01
9	2,106	0.67 ± 0.95[d]	2,213	0.73 ± 0.99[d]	2,393	0.64 ± 0.92[d]	2,441	0.64 ± 0.91[d]	5.184	<0.01
10	1,797	0.69 ± 0.89[e]	2,116	0.73 ± 0.94[e]	2,191	0.68 ± 0.96[e]	2,406	0.61 ± 0.89[e]	4.399	<0.01
11	2,000	0.71 ± 0.89[f]	1,788	0.78 ± 0.90[f]	2,058	0.71 ± 0.86[f]	2,176	0.68 ± 0.85[f]	4.209	<0.01
12	3,385	0.61 ± 0.82[g]	3,439	0.68 ± 0.83[g]	2,832	0.64 ± 0.79[g]	3,201	0.61 ± 0.81[g]	4.660	<0.01
13	2,815	0.53 ± 0.75[h]	3,384	0.59 ± 0.77[h]	3,347	0.57 ± 0.77[h]	2,735	0.51 ± 0.72[h]	4.714	<0.01
14	2,818	0.47 ± 0.68[i]	2,808	0.55 ± 0.75[i]	3,254	0.49 ± 0.71[i]	3,335	0.45 ± 0.72[i]	11.213	<0.01
Total	21,966	0.56 ± 0.88[j]	23,049	0.63 ± 0.89[j]	23,607	0.56 ± 0.86[j]	24,424	0.54 ± 0.94[j]	18.354	<0.01

[a]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 6, $p < 0.05$.
[b]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 7, $p < 0.05$.
[c]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 8, $p < 0.05$.
[d]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 9, $p < 0.05$.
[e]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 10, $p < 0.05$.
[f]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 11, $p < 0.05$.
[g]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 12, $p < 0.05$.
[h]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 13, $p < 0.05$.
[i]Significant statistical difference in 2019, 2020, 2021, and 2022 for age 14, $p < 0.05$.
[j]Significant statistical difference in 2019, 2020, 2021, and 2022 for total, $p < 0.05$.

TABLE 3 Detection rates of low weight, normal, overweight, and obesity among 6–14 years-old adolescents in Jinan City from 2019 to 2022.

Years	Low weight (numbers)	Normal (numbers)	Overweight (numbers)	Obesity (numbers)	Trend X^2	*P*	Cramer's *V*
Male					16.363	<0.01	0.021
2019	3.13% (363)	58.73% (6,820)	16.49% (1,915)	21.65% (2,515)[d]			
2020	3.59% (433)	56.27% (6,772)	16.53% (1,989)	23.61% (2,841)			
2021	3.50% (433)[a]	58.54% (7,242)	16.83% (2,082)	21.13% (2,614)			
2022	3.46% (442)	59.28% (7,570)[b]	17.47% (2,231)[c]	19.79% (2,528)			
Female					29.339	<0.01	0.018
2019	2.98% (309)	66.35% (6,869)	15.84% (1,640)[c]	14.83% (1,535)[d]			
2020	4.04% (445)	64.37% (7,090)	16.11% (1,774)	15.48% (1,705)			
2021	3.71% (417)	67.34% (7,566)	14.89% (1,673)	14.06% (1,580)			
2022	3.89% (453)[a]	68.28% (7,957)[b]	14.86% (1,732)	12.97% (1,511)			
Primary school					27.062	<0.01	0.020
2019	3.44% (445)	64.46% (8,346)	15.29% (1,980)	16.81% (2,177)[d]			
2020	4.90% (657)	63.67% (8,543)	15.34% (2,058)	16.09% (2,160)			
2021	4.54% (644)[a]	65.79% (9,325)[b]	14.63% (2,074)	15.04% (2,131)			
2022	4.30% (651)	65.44% (9,916)	15.31% (2,321)[c]	14.95% (2,265)			
Middle school					9.542	<0.01	0.025
2019	2.52% (227)	59.24% (5,343)	17.47% (1,575)	20.77% (1,873)			
2020	2.29% (221)	57.3% (5,519)	16.67% (1,605)	23.74% (2,286)			
2021	2.18% (206)	58.13% (5,483)	17.82% (1,681)[c]	21.87% (2,063)[d]			
2022	2.63% (244)[a]	60.53% (5,611)[b]	17.71% (1,642)	19.13% (1,774)			
Total					44.359	<0.01	0.018
2019	3.06% (672)	62.32% (13,689)	16.18% (3,555)	18.44% (4,050)[d]			
2020	3.81% (878)	61.01% (14,062)	15.89% (3,663)	19.29% (4,446)			
2021	3.60% (850)	62.73% (14,808)	15.90% (3,755)	17.77% (4,194)			
2022	3.66% (895)[a]	63.57% (15,527)[b]	16.23% (3,963)[c]	16.54% (4,039)			

[a]Comparison of the highest low weight rates in 2019, 2021, and 2022 with 2020, $p < 0.05$.
[b]Comparison of the highest normal rates in 2019, 2021, and 2022 with 2020, $p < 0.05$.
[c]Comparison of the highest overweight rates in 2019, 2021, and 2022 with 2020, $p < 0.05$.
[d]Comparison of the highest obesity rates in 2019, 2021, and 2022 with 2020, $p < 0.05$.

Conclusion

In 2020, the BMI *Z* score and obesity rate of 6–14 years-old adolescents exhibited a significant increase compared to 2019, and were controlled to decrease in 2021 and 2022. The normal body size proportion continued to rise, and adolescents of different age groups and genders exhibited similar development trends.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Ethics Committee of Shandong Normal University (2021036). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

GQ: Writing – original draft. HL: Data curation, Writing – review & editing. YQ: Data curation, Writing – review & editing. BL: Data curation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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3D indoor modeling and game theory based navigation for pre and post COVID-19 situation

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The COVID-19 pandemic has greatly affected human behavior, creating a need for individuals to be more cautious about health and safety protocols. People are becoming more aware of their surroundings and the importance of minimizing the risk of exposure to potential sources of infection. This shift in mindset is particularly important in indoor environments, especially hospitals, where there is a greater risk of virus transmission. The implementation of route planning in these areas, aimed at minimizing interaction and exposure, is crucial for positively influencing individual behavior. Accurate maps of buildings help provide location-based services, prepare for emergencies, and manage infrastructural facilities. There aren't any maps available for most installations, and there are no proven techniques to categorize features within indoor areas to provide location-based services. During a pandemic like COVID-19, the direct connection between the masses is one of the significant preventive steps. Hospitals are the main stakeholders in managing such situations. This study presents a novel method to create an adaptive 3D model of an indoor space to be used for localization and routing purposes. The proposed method infuses LiDAR-based data-driven methodology with a Quantum Geographic Information System (QGIS) model-driven process using game theory. The game theory determines the object localization and optimal path for COVID-19 patients in a real-time scenario using Nash equilibrium. Using the proposed method, comprehensive simulations and model experiments were done using QGIS to identify an optimized route. Dijkstra algorithm is used to determine the path assessment score after obtaining several path plans using dynamic programming. Additionally, Game theory generates path ordering based on the custom scenarios and user preference in the input path. In comparison to other approaches, the suggested way can minimize time and avoid congestion. It is demonstrated that the suggested technique satisfies the actual technical requirements in real-time. As we look forward to the post-COVID era, the tactics and insights gained during the pandemic hold significant value. The techniques used to improve indoor navigation and reduce interpersonal contact within healthcare facilities can be applied to maintain a continued emphasis on safety, hygiene, and effective space management in the long term. The use of three-dimensional (3D) modeling and optimization methodologies in the long-term planning and design of indoor spaces promotes resilience and flexibility, encouraging the adoption of sustainable and safe practices that extend beyond the current pandemic.

KEYWORDS

route planning, COVID-19, pandemic, game theory, simulation, localization

1 Introduction

The pandemic has changed behavior, increasing awareness of health measures (1). Hospitals need to plan routes strategically to reduce exposure and influence behavior. Global Navigation Satellite System (GNSS) and digital maps are indispensable for any navigation system. Digital mapping is collecting, compiling, and formatting geographic data into a virtual image. Primarily, this technology generates accurate representations of a particular area, including major roads and other points of interest within that area. The technology also allows the calculation of distances from one place to another. Most often, digital mapping is done for open geographic areas and is restricted to a demarcation of boundaries of roads, buildings, and other areas of interest only. Such information has proven to be fundamental for any offline navigation system. This could be why numerous studies have only discussed the deployment and optimization of challenges associated with outdoor navigation. Limited literature has promulgated the issues related to indoor navigation. A recent survey indicates that humans spend more than 90% of their time within indoor environments like homes, offices, malls, and colleges (2). These days, more than 150 companies are working on indoor positioning, indoor mapping, tracking, and navigation (3, 4). One such functionality was recently in demand within the healthcare industry during the COVID-19 outbreak (5).

Many patients who tested positive for COVID-19 required hospitalization, and hospitals had to deal with a heavy patient load. This contagious disease made enclosed spaces like hospitals more vulnerable for people working there. Subsequently, it was realized that indoor navigation systems (INSs) could help improve healthcare services and curtail the spread of infectious diseases like COVID-19. Direct contact or interaction with the crowd is the prime reason for the spread of COVID-19. Hospitals and COVID-19 isolation wards needed a viable solution to manage the crowd movement while ensuring minimal contact with COVID-19 patients or caregivers (6). In the last decade, indoor navigation has become a growing topic of choice for researchers. Mapping and modeling of indoor spaces are done to manage and monitor the infrastructure through location-based services. With the global expansion, approx. 95% of urban areas embrace visualizing smart cities, buildings, and infrastructure in three dimensions (3D) (7). Visualization based on 3D maps has recently been proven more effective than 2D maps for navigation and decision-making. The use of three-dimensional (3D) models is highly advantageous in representing spatial data, as it offers a more interactive and realistic visualization. 3D models have the potential to improve understanding of the relationships between different characteristics and their geographical layout. Visualization involves the deployment of multiple technologies, such as the Internet of Things (IoT), Building Information Model (BIM), and QGIS (8–10). QGIS is a widely used open-source Geographic Information System (GIS) that provides a comprehensive set of advanced tools for mapping, analyzing and generating spatial data. QGIS is a spatial modeling tool due to its extensive capabilities in geographic analysis, data visualization, and 3D modeling. The software's open-source nature and support from its community make it a versatile and cost-effective alternative, which aligns with the financial considerations of the research project (11). Additionally, the use of various plugins and capabilities within the QGIS software played a crucial role in developing intricate and comprehensive three-dimensional representations of the hospital structure and its surrounding environment. In the purview of the previously stated arguments, this manuscript emphasizes the following scientific contributions:

- To explore the feasibility of using 3D maps for indoor management of crowds.
- To propose a spatial distribution model for indoor environments using game theory and strategizing path optimizations.
- To evaluate the performance of the proposed model through case analysis.

Indoor location prediction and localization involve identifying the precise position or coordinates of an object, person, or device within a limited indoor area such as a building, floor, or room. Several technologies and methodologies, including Wi-Fi positioning, Bluetooth beacons, UltraWideBand, and Inertial Measurement Unit (IMU), can be used to achieve this objective. Location prediction requires projecting the future position or trajectory of an object or entity inside an indoor environment by utilizing past data, trends, or algorithms. However, determining the position inside indoor spaces can be challenging due to the complex and ever-changing characteristics of indoor settings.

In healthcare facilities, implementing location prediction and localization techniques can optimize indoor navigation for patients diagnosed with COVID-19. These strategies can effectively contribute to providing optimized routes and directions within the hospital premises. For instance, predicting the possible whereabouts of a patient within a facility can enhance the efficiency of healthcare personnel in navigating the premises, thereby reducing the risk of exposure. For case analysis, this study investigates the feasibility of deploying the proposed model within a medical facility offering treatment to COVID-19 patients. It intends to suggest optimized routes for the transit of COVID-19 patients and caregivers to ensure minimal contact with other patients and visitors.

The rest of this paper is structured as follows. After the introduction section, section 2 details the literature studies of Indoor 3D modeling, Indoor routing, localization and routing in COVID-19-related indoor premises. The methodology of creating a 3D model of a building using a 2D map and route optimization is described in Section 3. A case study using a hospital building for the proposed approach is described in Section 4. The result discussion related to the case analysis is summarized in section 4. Section 5 provides the discussion and future scope of the presented research.

2 Related work

This section includes the paper published in 2016–2023 related to route optimization within indoor environments. The backtracking technique to adopt the traveling salesman problem for route optimization was presented as a novel method to organize tourist itineraries inside a place (12). Similarly, a dynamic technique that uses real-time situation awareness to optimize indoor evacuation routes was proposed. The escape path is dynamically optimized using information about the changing internal environment and a real-time understanding of fire characteristics (13). In the context of smart buildings, a creative solution that manages visitors within hotels, conference centers, universities, and hospitals during the COVID-19

and other pandemics has been planned (5). A reliable and affordable indoor navigation system was proposed to navigate people inside smart buildings. The primary contribution was a new proximity-based navigation system that used beacon data to determine the user's location. Further, it finds the ideal route for navigating the edge computing infrastructure and provides access to the user over a smartphone (6). After analyzing the influencing variables, a multi-route choice model based on game theory was proposed for path recommendation (14).

As buildings become more extensive, accurate spatial information is crucial for creating indoor route plans. Building information modeling (BIM) technology, which can provide detailed semantic and geometric information, is required to improve indoor route planning. A 3D Geographic Information System (GIS) environment to create a Historic Building Information Modeling (HBIM) model to provide thorough and practical documentation for multi-scale evaluations of cultural heritage was proposed (15). The community of architectural engineering and construction (AEC) benefits greatly from the creation of 3D building models. However, it is difficult and time-consuming to manually create a polygonal 3D model of a collection of floor plans. Currently, scientists are attempting to automate a 3D building's model reconstruction (16, 17). The development of an indoor space model initially requires the right implementation of sensors to gather data from the indoor environment, which aids in precisely modeling the entire indoor environment and contributes to the effectiveness of the reconstructed model (11, 18, 19). Different technologies and techniques were used in various models for path optimization and route planning, as summarized in Table 1.

Various technologies such as radio frequency (RF), computer vision, and sensors are used for indoor positioning and navigation, including Wi-Fi, Bluetooth, and ultra-wideband (UWB) (27). The study introduces an indoor positioning system that utilizes STM32 and UWB technology. The system demonstrates a notable accuracy level of 20 cm (28). Similarly, a study presents a wireless-inertial fusion positioning system called SmartFPS, which utilizes a stateful LSTM network and a multi-task learning approach. Field testing has demonstrated that SmartFPS exhibits superior performance compared to filter-based approaches, as it achieves an average placement accuracy of 0.575 meters for various pedestrian scenarios (29). Furthermore, a hybrid method for improving indoor positioning accuracy using Bluetooth Low Energy (BLE) fingerprinting and PDR was proposed. Similarly, the use of a Radio Signal Strength Indicator (RSSI) and Pedestrian Dead Reckoning (PDR) for indoor positioning achieves a 68 cm positioning accuracy through sensor fusion (30). The experiment uses the Kalman Filter as a benchmark, and ANN and SVR are combined to achieve a positioning root-mean-squared error of 212.21 cm (31).

3 Methodology

Visualizing the precise location of building rooms and utilities in 3D helps visually communicate indoor spatial information. 3D visualization would decrease routing uncertainty inside the structures and help in more informed navigation strategies. LiDAR is used to generate point clouds. These point clouds representing features in 3D space are produced using Light Detection And Ranging (LiDAR) scanners. Despite the rapid advancement of LiDAR-based technologies to enhance data collection capabilities, there are no standardized procedures for classifying point cloud data to extract features of relevance for indoor environments. A manual process was developed to efficiently classify indoor point clouds using LiDAR technology, with a specific focus on identifying traits that are relevant to public safety personnel (32). A proposed unsupervised segmentation method for large-scale 3D point clouds has the potential to improve object-based classification (33). Moreover, a unique approach for classifying indoor components with few labeled samples was introduced to tackle the challenge of insufficient data for training deep learning algorithms (34). Researchers have acknowledged the absence of standardized protocols for point cloud data classification, particularly for extracting relevant features in indoor settings.

Using Volunteered Geographical Information (VGI) is prominently used for the virtual creation of geographic information (35). The third choice involves digitizing the building information for future usage using professional GIS tools like Quantum GIS (QGIS) (36). QGIS provides geometric representation for spatial analysis and semantic representation of building models with different features. For example, if we give the building details like room, floor, and walls, it

TABLE 1 Route planning technologies for different models.

Reference	Year	Model used	Algorithm	Technologies
Carrera et al. (20)	2018	Stochastic model	Tracking Algorithms	Wireless fidelity (Wifi) received signal strength indicator (RSSI), Smartphones.
Fisac et al. (21)	2019	Non deterministic model	Game theoretic trajectory planning algorithm	Autonomous driving technologies
Dogan et al. (22)	2020	Two Dimensional model	Fuzzy c-means clustering algorithm	Bluetooth based technology
Hassija et al. (23)	2020	Drone charging model	Scheduling algorithm	Hedera hashgraph technology
Alamri (24)	2021	Ontology model	Routing algorithm & density rules algorithm	WiFi, Bluetooth, RFID, semantic web technology
Shin and Moon (25)	2021	YOLOv4 model	DeepSORT, multiple object tracking algorithm	Computer Vision technology
Jia et al. (26)	2022	Neural network model	Fingerprinting	Wifi RSSI

can be used for various applications (37). The relational data model used by QGIS makes it simple to represent information from a variety of GIS data formats, including Esri shapefiles and GeoJSON. The mapping of a more intricate data model is still necessary. Additionally, we think that QGIS can transform 3D building models because of its extensive support for GIS formats and the use of the Geospatial Data Abstraction Library (GDAL).

Game theory is an efficient mathematical theory to address conflict and cooperation. It abstracts all conflict and cooperative phenomena into a game model with three components: participants, strategy, and payout mechanism (38). The key concept is to treat the model-driven and data-driven evaluating techniques as players in a game. The fusion accuracy and variance are regarded as game information, with the weight of the two approaches serving as the game's weight. The methodology section is divided into four subsections: data collection, spatial data creation, visualization, rendering of 3D information, and route optimization. The study of optimized indoor navigation for COVID-19 patients and hospital resource allocation through a 3D hospital model creation and simulation is shown in Figure 1. The model used a priority queue and Dijkstra algorithm to find the quickest and safest paths. Game theory and Nash equilibrium were used to find the most efficient routes incorporating hospital factors. The methodology was validated through practical trials in a multi-story building, with positive results. This provides a solid foundation for addressing indoor navigation and resource allocation in healthcare facilities, particularly during the COVID-19 pandemic. Facts related to the attributes of a building were accumulated during data collection. These fundamental facts were fetched from OpenStreetMap (39, 40). After including the available 2D information from OSM, a 3D model was created using spatial statistics. The 3D version was visualized and rendered with the usage of plugins. Figure 1 visualizes the methodology of creating a 3D model. When we have a 3D perspective, game theoretic routing methods are used to obtain the ideal path.

3.1 Data collection

The following procedure was adopted to collect the spatial information during the experimental setup:

(a) Collect the ground control points by using a LiDAR sensor (Latitude and longitude).
(b) Open layer plugins like Google map, OpenStreetMap, and Bing Map were used to verify the Latitude and Longitude points related to the identified location.
(c) This georeferencing is projected in the decided Coordinate Reference System (CRS), which is supported as the raster layer of the map.
(d) QGIS supports dxf files, shapefiles, map info, PostGIS, and personal geodatabase. Shapefile equipment creates the vector layer over the georeferenced raster layer map.
(e) To express the congestion factor and shorten the computation time, we opt for the most crucial variable, i.e., population density.

All the vector layers are required for digitizing the map. The various features of a building are described in Table 2, along with their mapping method.

3.2 Spatial data management

Most high-level data processing procedures are automated in the QGIS. The tools are arranged as distinct toolboxes called geoprocessing

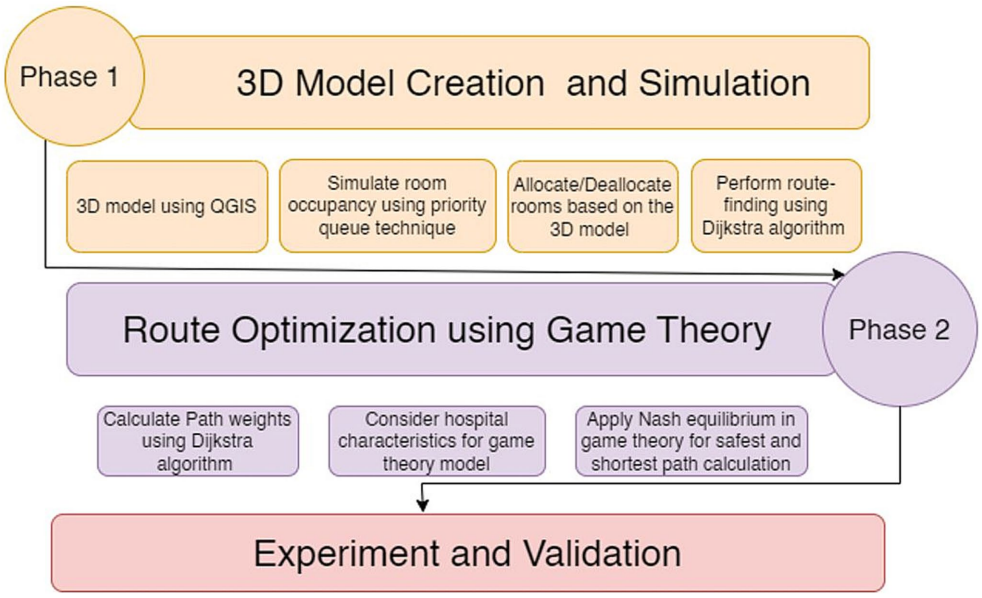

FIGURE 1
Methodology for 3D indoor modeling and game theory-based navigation.

TABLE 2 Feature description and mapping method.

QGIS indoors feature classes	Description	Mapping method
Facilities	Building in data collection	Digitize as a polygon in QGIS
Levels	Separate floors of the building	Digitize as a polygon in QGIS
Walls	Separate rooms within one floor	Digitize as line in QGIS
Units	The space is enclosed by a floor and separated by walls	Digitize as a polygon in QGIS
Points of interest	Population density or locations where the path will be decided	Points

tools. Figure 1 shows the tools in the correct order. Creating a SpatiaLite database is the first step in developing the information modeling process that supports the management of indoor GIS data within QGIS. The use of a vector layer allows the creation of new shapefiles.

The input data used to build the topological model of the building might originate from a variety of sources and forms. Vector data, such as Shapefiles (shp.), AutoCAD (dwg), or MicroStation (dgn) files, are frequently used to store data and information in the form of floor plans. Additionally, the relevant data from the BIM model can be exported and used to create floor plans as Shape, Vector, or CAD files. If data related to floor plans is already accessible in picture form, it must first be georeferenced before being manually digitized. The floor map will then be ready after importing vector shape files using QGIS Toolbox. The many indoor feature classes include different geometry types, such as polygons, lines, points, and multipoints. Information like an id, height, name, etc., is contained in these feature classes. Additionally, users of QGIS can import Map Layouts. The user must assess and fix any potential issues after running this operation.

The final step is to create a 3D model by using the collected information. To visualize the model in three dimensions, one can incorporate the altitude/height data into the project by double-clicking the layer properties. Each layer has features associated with it, such as id, height, name, etc. The altitude attribute can show the desired altitude by using Equation 1. A 3D model can be generated using a 2D map, as shown in Figure 2.

$$Expression = feature * n \tag{1}$$

Where the feature is id and n is the number of height.

3.2.1 Visualization and rendering of 3D model

This component is used for determining the precise location and heights of a building or any other point features within the building. LiDAR and conventional methods (such as tape measures, theodolites, total stations, and leveling instruments) were employed to gather information on the building's feature points. Additionally, Architectural drawings and blueprints, if accessible, may be utilized as a component of the conventional data-gathering process. The probable topological errors that can affect the visualization of the model are detected and eliminated. After self-inspection of collected data, duplicate data are removed. Then, a LiDAR sensor is used to estimate each point's height within the shapefile. The QGIS plugin "qgis2three.js" was subsequently used to create a 3D model of an entire building.

3.2.2 Route optimization based on game theory

Many elements may impact the path selection criteria within a data model. Game theory is used to select the path by using a path-benefit parameter. This parameter is primary to optimize the data model. This value is then provided as an input parameter for the game theory to select the optimal path. Game theory is a particularly effective mathematical framework for defining and addressing path-planning issues (41). The use of game theory allows us to create models that capture the complex decision-making processes of various stakeholders in the medical environment. It also helps us optimize the allocation of resources, such as unoccupied rooms and the most efficient routes. The Nash equilibrium concept in game theory is particularly useful for strategic path planning, finding the right balance between safety, efficiency, and patient preferences. Finally, it promotes fairness and effectiveness in allocating resources and navigation techniques, which are crucial for a successful indoor navigation system in hospitals.

It examines the interactions between two or more rational agents called players. In these situations, other players, known as the environment, are typically added to the game to represent the uncertainty that influences the players' decisions. A wide range of factors influences the decision of which strategy to use. The most crucial is the player's utility function, which measures how satisfied the player is with each potential strategy profile. Since the outcome of a game also depends on the decisions made by the other players, in most situations, using a strategy that enables a player to maximize utility may result in a noticeably lesser payoff. To put it another way, it is typically straightforward for other players to retaliate against the greedy strategy. This fact has prompted numerous definitions of strategy optimality and logical player conduct. The Nash equilibrium is perhaps the term most frequently used in this context. It refers to any strategy profile from which one player cannot benefit from a unilateral deviation. In this experiment, multiple entry and exit doors are available to the patient. The patient looking for the room acts as a player, and the natural parameters are room location, patient condition, hospital crowd information, and available routes. Mathematically, a Nash solution is a pair of decisions a*, b* that satisfy the inequalities in a game with two users. Here, a and b symbolize the decision variables of users 1 and 2, respectively. At the same time, U1(a, b) and U2(a, b) denote the utilities that these users desire to maximize, as shown in Equations 2, 3 (42).

$$U1(a*,b*) >= U1(a,b*) \; for\ all\ a \in A \tag{2}$$

$$U1(a*,b*) >= U1(a*,b) \; for\ all\ b \in B \tag{3}$$

where A and B are the corresponding decision spaces for the two users. The concept of the Nash solution is appealing because it results in an equilibrium condition that ensures no user can gain by

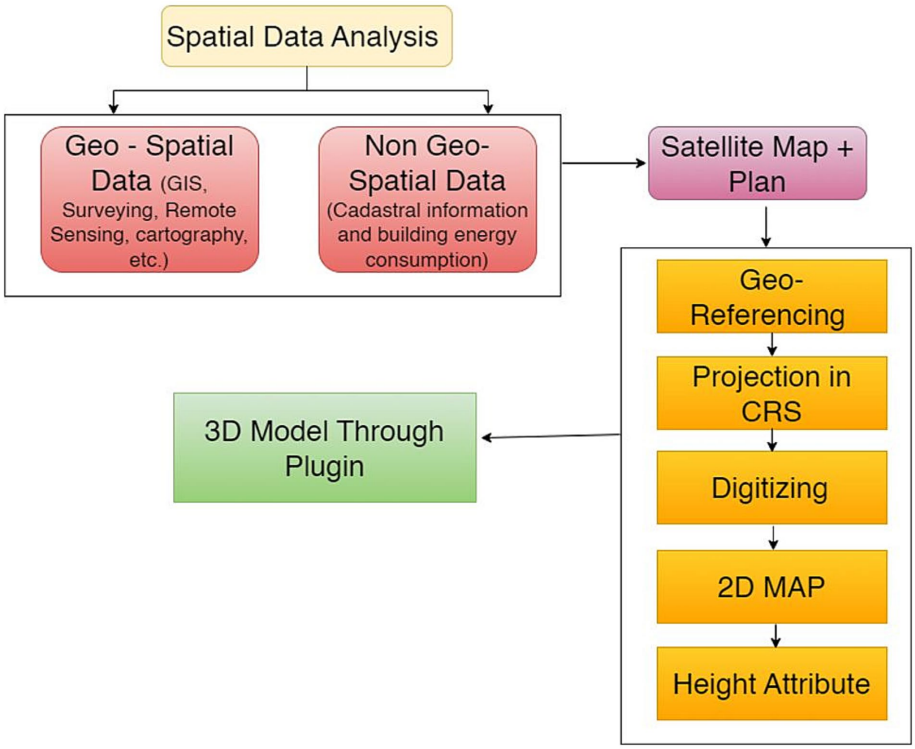

FIGURE 2
Conceptual chart for generating a 3D model from a 2D map using the GIS platform.

unilaterally departing from its Nash decision (42). The mapping of relationships between all routes is the Nash equilibrium that the game theory model derives, making it possible to identify the best path for patients.

The optimum path may not always be the shortest since different network components move at different speeds. As a result, the problem of selecting the optimal route in an emergency would be to select the quickest and safest route to the destinations while accounting for walking speed on horizontal indoor floors, vertical walking speed on stairs, and vertical elevator walking speed. We have predicated the cost of each edge based on the time required to cross that edge, which can be calculated using the Equation 4 below (43):

$$\begin{matrix} \textit{Time to traverse} \\ \textit{the edge} \end{matrix} = \begin{matrix} \textit{Distance of} \dfrac{\textit{edge}}{\textit{speed}} \textit{of} \\ \textit{traversing the edge} \end{matrix} \tag{4}$$

The time to cross the edge equals the edge's length times its speed.

The fastest route between any two places is determined using the Dijkstra algorithm and the aforementioned edge costs. Therefore, using the following calculation (Equation 5), the path with the shortest overall traversing time is the fastest way to get from A to B (43).

$$T = \min \sum_{i£1}^{n} \left[\left(\frac{D_h}{S_w} \right) + \left(\frac{D_v}{S_{Stair}} \right) + \left(\frac{D_{path}}{S_{path}} \right) \right] route \tag{5}$$

Where T is a total traversing path, $_{Dh}$ and D_v are the Distance walked Horizontally and Distance walked vertically, Dpath is the Distance traversed on the path, S_w is the speed of horizontal walking, S_{stair} is the speed of vertical walking, S_{path} is the speed on the path, and L is the total Distance traveled ($L = D_{(vertical)} + D_{(horizontal)} + D_{(path)}$).

The navigation path between two desired destinations can be determined using Dijkstra based on dynamic programming, and the fastest path can be found. Dynamic programming can be used to solve the node relation graph in the best possible way. The patient can choose their commute by looking for the shortest Distance or the fewest nodes. The infection rate impacts COVID patients' movement (Intensive, moderate and normal). The average pace of a patient using crutches ranges from 0.63 to 1.35 meters per second (m/s), walking sticks from 0.26 to 1.60 m/s, an electric wheelchair from 0.85 to 0.93 m/s, and a manual chair or stretcher from 0.13 to 1.35 m/s (44). The patient's evacuation time may be impacted by the number of individuals, their density, their movement pace, and the breadth of the corridors.

We pairwise compare the two paths when there are several options before selecting the optimal one. According to the generic definition of the game, G = R, S, A, and U, we have the following:

1. Patient: The definition of the ith route is Ri, iN, N = 1, 2… n.
2. R_i is S_i, S_i [0, G_i], I belong to N in the strategy space. Ri leads us to believe that Gi has the greatest number of patients.
3. The payout function of the game is $U(x_1,\ldots, x_n)$; to put it more precisely, let.

$$U\left(x_1, x_2 \ldots\ldots x_n\right) = \left\{ \sum_{i=1}^{n} rs_i^p * t_i + \sum_{j=1}^{m} rs_j^l * t_j \right\} \quad (6)$$

Where rs_i^p is the suggested score for the ith path, and rs_j^l is the suggested score for the ith rooms, as mentioned in Equation 6 (44). In addition, n is the number of roads, m is the number of rooms, and t is the amount of time spent traveling or in a room. The Nash equilibrium represents the mapping relationship between all routes that the game theory model derives, making it possible to identify the best course of travel.

4 Case study

The geographical area of a multistoried building with multiple entry and exit options at the GPS coordinates 30° 30′ 59.2524" N and 76° 39′ 33.1560″ E has been considered for this experiment. There were three floors in the building. The Building Information Model (BIM) model was created using a spatial database in QGIS after collecting LiDAR data. Elements such as walls, rooms, floors and their respective attributes have been mentioned separately in shape files for each floor. TFmini-s handheld LiDAR sensor with an accuracy of 0.1–12 meters was used to collect data at medium walking speed. The scan time was less than equal to 30 s. These techniques included moving gradually and without abrupt changes in direction, keeping motion to two axes at once, and more. Scanning a large multi-story building of 746.889 m^2 (Cartesian) took hours, depending on the characteristics of the building.

4.1 2D map

Coordinate Reference System, i.e., EPSG: 4326-GS 84 and Latitude and longitude were used to locate the building on Google Maps. After measuring the dimensions of different areas, these points are extracted in the QGIS version 3.24.1. The building block has a different feature in the form of polygon layers. Each polygon has its axis as Latitude, longitude, height, and area. The Latitude and longitude of each Floor come from the georeferenced map.

4.2 Visualize 3D data model

The subsequent processing steps were carried out in QGIS software using the Qgis2three.js plugin. Qgis2three.js plugin uses the Three.js Library to visualize the floor map in three dimensions. It is compatible with any web browser that supports WebGL. The following steps were performed to load all data into QGIS:

(1) Creating the two-dimensional model of a building required the development of the floor plans to develop a 3D model of the same.
(2) After successfully merging the floor-to-floor height into the level and creating all the floor plans for all levels, the walls may be added to produce a simple three-dimensional model or block model.
(3) After confirming the height data, the level information is automatically incorporated within the QGIS2threejs. exporter window.
(4) There was a need to add details to the fundamental three-dimensional model, such as opacity expression and color-feature style, to distinguish each feature class included in the QGIS model's hierarchical structure.
(5) The inner and outer walls were added by choosing the wall option from the layer window. The wall type and dimension can be chosen and altered as desired. A basic 3D model is created after adding all the walls.
(6) After creating the primary 3D model, specific details related to rooms, stairs, reception area, seating area and other components were added.
(7) Introduce the height in each polygon layer in the properties/attribute table by adding the new height column. Then, with the plugin "qgis2threegs," the 3D model is directly generated.

4.3 Route optimization based on game theory

In this study, the optimal path must be determined to find the safest route to transit COVID-19 patients. We evaluated different options before selecting the optimal path. The chosen building has three entrances with a dedicated block assigned to COVID-19 patients.

As shown in Figure 3, a Node Relational Structure (NRS) is proposed to represent the internal architecture of the building. The model represents the facilities as a graph based on the relationships between the nodes and edges to visualize the structure of a room in a building. A simulated model may specifically describe facilities available at a location.

The graph includes nodes N and edges E. The hypergraph of the building is divided into corridors, rooms, bridges, and floors. The network topology created using the NRS model is shown in Figure 3. There are three floors in the building block. Each Level, or F1, F2 and F3, constitutes a separate sub-drawing. A stairway links F1, F2, and F3. In each sub-diagram, a room and a hallway serve as the nodes and edge connections can join the two spaces together. The corridor node is expanded to create an extension node between each room to accurately depict the Distance between the two nodes. Finding the shortest path and safest in this method allows for the precise measurement of the path length. Corridor node is increased to X1, X2, X3, X4, X5, and X6, for instance.

The relationship for connected nodes G = (F1 U F2 U F3), where F1, F2 and F3 are different floors. F = {X U Y U E) where X contains path points, Y contains nodes/rooms/cabins, and E is for entry and exit. F1 = (X1, X2, X3, X4, X5, X6, S1, S2, E1, E2, L1, L2) R_g, F2 = (X7, X8, X9, X10, X11, X12, S3, S4, L1, L2) R_f, F3 = (X13, X14, X15, X16, X17, X18, S5, S6, L1, L2) R_s, R_g = (Y1, Y2, Y3, Y4, Y5, Y6), R_f = (Y7, Y8, Y9, Y10, Y11, Y12) and R_s = (Y13, Y14, Y15, Y16, Y17, Y18). Where G is the union of F1, F2, and F3 floors, and S indicates the stairs. E1, E2 and E3 are entry and exit points for quarantine or recovered patients on the ground floor. L1 and L2 are elevators on the first and second floors. Rooms were further divided into various cabins. The

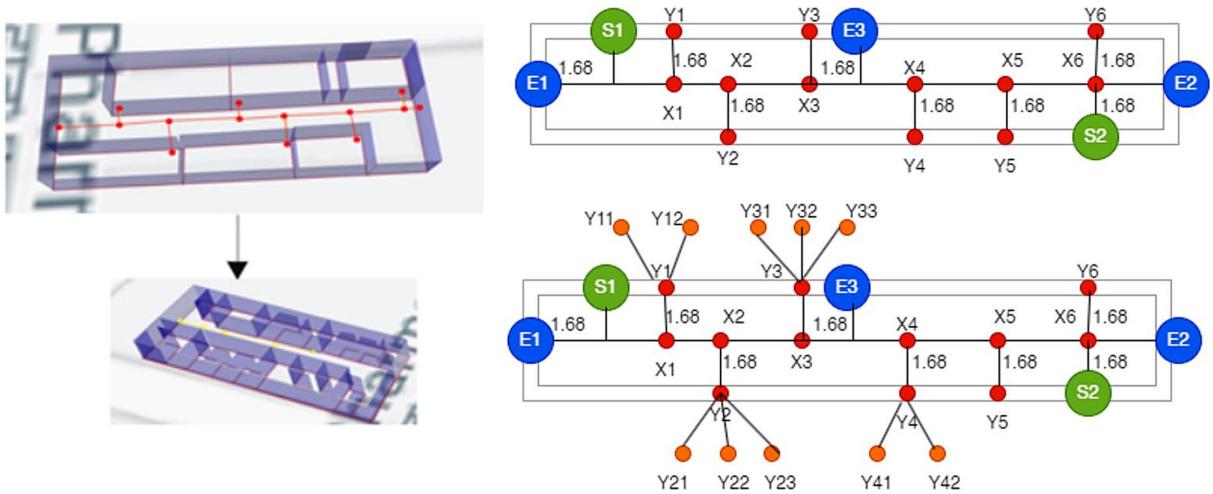

FIGURE 3
A model of a three-dimensional building with hierarchical relationships.

TABLE 3 Optimal route and associated attributes from node to successor nodes using a fusion approach.

Sr. no.	Node	Immediate precursor	Immediate successor	Optimized route from node to successor
1	X1	E1, S1, L1	X2, Y1	3.735 m
2	X2	X1	X3, Y2	8.557 m
3	X3	X2	X4, Y3	2.177 m
4	X4	X3	X5, Y4	3.628 m
5	X5	X4	X6, Y5	5.180 m
6	X6	X5	E2, Y6, S2, L2	5.770 m
7	Y1	X1	Y11, Y12	1.68 m (from the center of the corridor)
8	Y2	X2	Y21, Y22, Y23	1.68 m (from the center of the corridor)
9	Y3	X3	Y31, Y32, Y33	1.68 m (from the center of the corridor)
10	Y4	X4	Y41, Y42	1.68 m (from the center of the corridor)
11	Y5	X5	-	
12	Y6	X6	-	
13	E1		E2	30.880 m
14	E1		E3	19.560 m

optimized route from node to successor is calculated through a fusion approach, as shown in Table 3.

A game theory model was applied to address the issue of repetition. Patients and methods of selection of rooms are included in the model. Incorporating game theory principles into the process of room allocation and deallocation allows for the most efficient use of available rooms, considering factors such as patient requirements, current room occupancy, and other pertinent situations within the hospital setting. This approach facilitates efficient queue management, reduces interpersonal encounters, and promotes adherence to social distancing protocols within the hospital premises, ultimately leading to a safer navigation experience for patients. Game theory models interactions between patients, hospital staff, and administrators to determine the best course of action that ensures safety and efficiency. By creating a game where participants decide the best routes and allocate rooms, aiming to identify the most secure and efficient path for patients while optimizing the distribution of resources.

First, each room is considered a node (V); to create a weighted graph, each edge (E) is assigned the measured Distance in meters. We build a weighted network in which each edge's weight equals the Distance between any two nodes. The priority queue (PQ) is used to determine the shortest path after implementing the adjacency of the

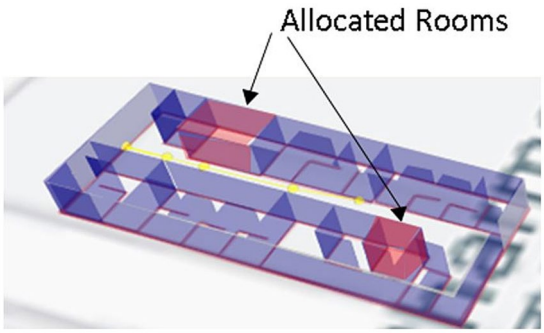

FIGURE 4
Allocation of rooms.

relevant matrix using this network. A PQ algorithm is utilized to assign and release rooms from COVID-19 patients while attempting to minimize patient contact while crossing hallways, as shown in Figure 4. The vacant room having the shortest path is given to the patient at preference. When a COVID-19 patient is healed, they can leave the room with little to no contact with other patients. The steps of allocation and deallocation are mentioned in Table 4.

For example, in a route network, COVID patients are given access to some vacant rooms, and separate virtual paths are made by splitting the accessible paths. A parallel route model for COVID patients may consider each virtual path as a route. Patients may be limited to only a certain number of routes (depending on the congestion) between any two nodes in a route by employing room allocation and deallocation information. The path weight is evaluated using the simulation method from QGIS as the selection index for the path selection. Later, in the suggested system, the best path is selected using game theory, and the Nash equilibrium is obtained based on the path weight produced by the fusion approach. Each path is given a weight based on its Distance. Path A is the safest route with the fewest transmission nodes, followed by Path B. Patient-assigned vacant rooms will be determined by priority queue, and patients can select the quickest and safest routes according to Nash equilibrium. Patients are free to choose their path without being aware of other patients' choices. The proposed strategy can shorten travel times and ease levels of congestion, according to experimental data from the building block, as shown in Figure 5.

A geometric network model integrates the topological network model with the geometric data. It would allow for cost computation (based on Distance or optimality) and visualization, as illustrated in Figure 6. Based on a geometric network model where rooms and spaces are connected to corridors, stairs, and elevators connect the levels, the 3D interior network dataset for the sample building was created, as shown in Figure 7.

Another output of the model that is provided based on the level of contamination in various locations and quick routing is the lengths of the shortest, safest short, or optimized safe paths. The formula shown below was defined to calculate the probability of infection (37),

$$n_v = \sum_{i=0}^{m} \left(\left(\frac{L}{v} \right) * P_t(i) * \gamma_b \right). \tag{7}$$

TABLE 4 Algorithm for room allocation and deallocation based on route algorithm.

Algorithm (LR, C): Where C is the total number of available rooms, and LR is the list of available rooms. N is the total number of patients, and R_f is the rooms on the first Floor. Establish a priority queue PQ with a size equal to the total rooms (NR). PQ is the priority queue.

```
Allocation:
    PQ.Create(NR)
    Initialize N:=1
    Do the following for every registered patient
        Yi = Allocate a room to the patient using PQ.Delete()
        LR = extract(LR,Yi)
        C = C − 1
        If N > Yf
            Shift patient to f + 1th Floor
        N=N + 1
    Repeat until LR is not empty

Deallocation: N=N-1
            LR = add(LR, Yi)
            PQ. Insert (Yi, H).
            C=C + 1
PQ methods
Create (NR). Establish a priority queue PQ size equal to the total rooms (NR).
Insert (Yi, H). Add Yi room to the priority queue following its minimum Distance from entry.
Find closest (T). Take out room from priority queue with minimum Distance from point T.
Delete(H): Delete the first node with minimum Distance from entry.
```

$$Infection\ Probability = nv \,/\, Infection\ threshold \times 100 \tag{8}$$

L is the length of the offered shortest, safest short path, or optimum safe path. V is the average speed at which a person moves. P_t (i) represents the amount of contamination at point i. γ_b represent the infection rate.

The Node relation model can be used to determine the best (fastest) routes between any two places inside the building after creating the interior network dataset with the necessary edge costs and connecting the indoor network to the road network (Table 5). This would give emergency personnel a rough idea of the length and Distance needed to get to the desired location inside the structure.

Graph theory and Nash equilibrium can be useful to model the behavior of patients in a corridor and to identify strategies that can reduce congestion. However, it is important to note that the effectiveness of these approaches will depend on the accuracy of the model and the ability to implement interventions that are feasible and operative in practice. To address the congestion, some approaches are taken into consideration (45–47):

(1) Identification of the relevant variable and parameters: It includes the number of patients, the physical layout of the corridor, the location of destination, and the time required for patients to travel through the corridor.
(2) Game formulation as a mathematical model: this involves defining the payoff function of a game theory for each patient, which represents their patient's objective in the game. The

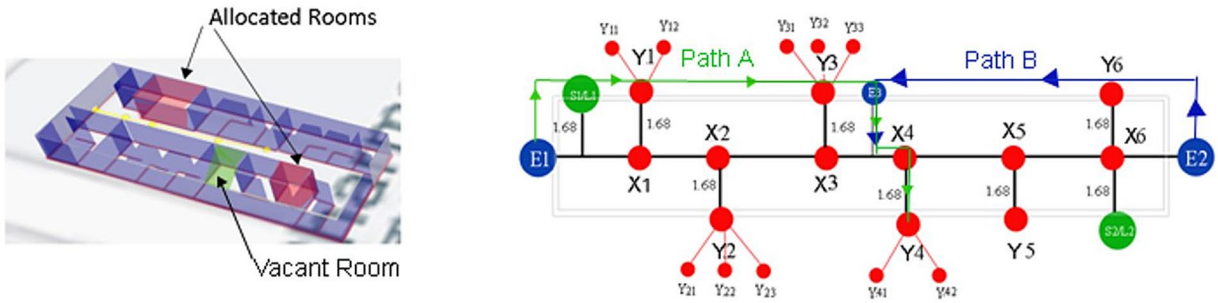

FIGURE 5
Safest path for a vacant room.

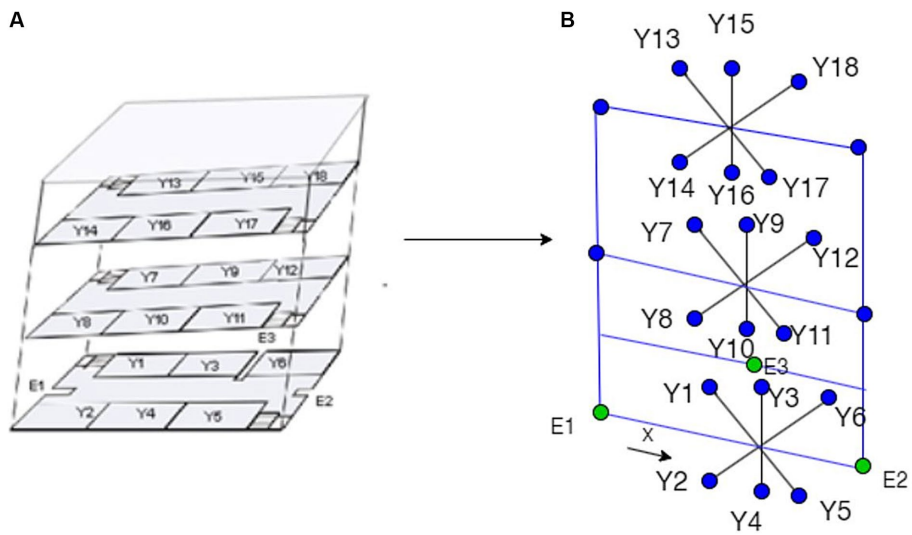

FIGURE 6
Building the geometric network model **(A)** 3D building model **(B)** topological model.

payoff function depends upon travel time, the Distance traveled, or other factors related to hospital facilities.

(3) Design interventions to reduce congestion: Based on the results of the game analysis, interventions be used to can reduce congestion. These include changing the physical layout of the corridor, providing signage or other communication tools to guide patient flow, or implementing scheduling policies that spread out patient arrivals and departure.

For better comparison and visualization, we took into consideration a test scenario of a simple storey structure to assess the efficacy of this 3D model in decision-making and improving interior routing times. The task of navigation has been tested on 10 individuals, and the average amount of time it took each of them to go a specific distance from point E2 to point Y17 has been calculated. As a result of this evaluation, a small error or lack of information could result in a significant delay in reaching various points inside buildings. Table 6 shows the average of the computed time and Distance.

In this study, the data from LiDAR sensors were combined with a simulated model to create a fusion strategy that was based on game theory. There might be differences between established and actual models. Even if there are errors in the developed model, changing the game strategy can still increase the precision of the projected results. The model-driven approach's biggest drawback is the need to build an extremely accurate model. This could decrease the accuracy of the position estimate findings and potentially cause the algorithm to diverge. This model makes use of the mathematical framework developed in the model-driven technique to suppress the estimation divergence brought on by the measurement error in the data-driven method. The complementing benefits of the two estimation approaches, which operate on various principles, are realized through this study.

Most studies conducted so far focus on objectives, such as network modeling, indoor routing, or visualization goals, making it difficult to draw attention to other crucial data needed for emergency response. There have also been some attempts to use CityGML and Building

Information Modeling (BIM) for indoor spatial modeling. However, these models either lack spatial analytical capabilities since they were created for viewing purposes or because they contain extremely complicated architectural engineering elements, as shown in Table 7.

5 Discussion

In COVID-19 and post-COVID-19, applying this approach within indoor areas can significantly improve the ability to reach the destination safely. This study uses an innovative indoor navigation system for a hospital building to provide an optimized route for COVID-19 patients. This research provides route optimization in a building by including queue management, intelligent navigation of spaces to minimize human interaction, and social distancing safety mechanisms. The proposed research work was conducted in two phases. In phase 1, QGIS software was used to design the 3D model of a building. The designed model was used as a simulation to examine room occupancy using the priority queue technique. The designed 3D model was further used for the room allocation/ deallocation and route-finding process. For the route-finding process, the Dijkstra algorithm and game theory were used in the second phase of this research. Path weights for the game theory were calculated using the Dijkstra algorithm. In this phase, game theory used the concept of Nash equilibrium to identify the best course of action that is the safest and shortest path. For the safest and shortest path calculation, the game theory model uses hospital characteristics like vacant rooms, Distance, corridors, facilities, staff, people density on the path, and speed of the patient. To validate the design framework, an experiment was conducted on a multi-story building located at GPS coordinates 30° 30′ 59.2524" N and 76° 39′ 33.1560″ E with multiple entry and exit options. The shortest and shortest path for 10 individuals was calculated on eight different routes. According to the performed result analysis, it has been observed that by prioritizing vacant rooms based on patient need and using the most efficient routing algorithm, the simulation optimizes the flow of patients through the hospital, minimizing congestion and wait times. The incorporation of Nash equilibrium ensures that all patients, staff, and administrators have their needs considered, leading to a fair and efficient allocation of resources. This research study also provides the comparison of the proposed framework with other methodologies, and it is observed that overall, this framework has the potential to provide the safest and safest route to the patient by considering the hospital's current situation and makes it a promising solution for managing hospital facilities in a more effective and sustainable way. The forthcoming research will focus on integrating real-time data and using the Internet of Things (IoT) and machine learning techniques to develop predictive models that allow us to make dynamic adjustments to paths. The research will also incorporate augmented reality to improve navigation. This research will collect user

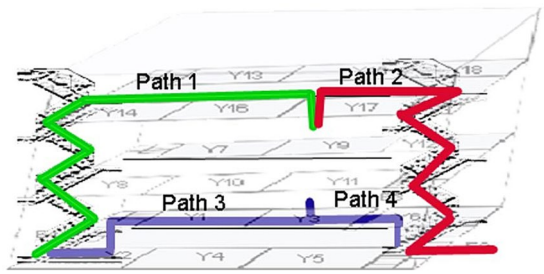

FIGURE 7
Navigation routes from source to destination.

TABLE 5 Navigation path between selected nodes.

Sr. No.	Start	End	Dijkshtra path	Nodes covered from source to destination	Distance
1	E1	Y4	E1->X1->X2->X3->X4->Y4	4	23.512 m (Shortest)
	E1	Y4	E1->E3->X4->Y4	2	33.562 m (Safest)
2	E2	Y4	E2->X6->X5->X4->Y4	3	16.175 m (Shortest)
	E2	Y4	E2->E3->X4->Y4	2	25.882 m (Safest)
3	E1	Y17	E1->S1/L1->Y14->Y16->Y17	2	29.345 m
	E2	Y17	E2->S2/L2->Y17	0	11.456 m (safest and shortest)
	E3	Y17	E3->Y1->Y2->S1/L1->Y14->Y16->Y17	4	29.675 m
	E3	Y17	E3->Y5->S2/L2->Y17	1	19.987 m

TABLE 6 Comparison of proposed model with existing model.

	Without 3D visualization and Dijskhtra algorithm	With 3D visualization and Dijkshtra algorithm using dynamic programming	Time difference
Comparison of Dijkshtra with proposed model	95 s. 32.341 m	72 s. 22.315 m	23 s. 10.026 m

TABLE 7 Relevant studies on 3D models: a comprehensive overview of research findings.

Reference	Year	Database	Software	Tools and technology	Algorithm/ Plugins	Output in dimension
Aleksandrov et al. (48)	2019	PostGIS	QGIS	LiDAR	CityGML	3D Outdoor
Liu et al. (8)	2020	PostgresSQL	Revit, AutoCAD, Blender	Python, Java	Map Matching, Path Planning	3D
Ahmad et al. (49)	2020	JSON files	Unity 3D	Mixed Reality Toolkit, Wi-Fi, Augmented reality	the k-nearest neighboring algorithm, machine learning algorithms	3D
Ma et al. (50)	2021	GIS database	AR-GIS	Augmented Reality, BLE, Inertial Sensor	Multi-sensor fusion-based algorithm, particle filter	3D
Trybała and Gattner (51)	2021	ESRI	ArcGIS	Geoprocessing tools, Python	Dijkstra's, Hill editing and metaheuristic Algorithms	3D
Aziz et al. (52)	2021	Inbuilt database	Phantom 3, Agisoft, Dji GO app	Camera and Unmanned Aerial Vehicles	Inbuilt algorithm of application-	3D
Ours		PostGIS	QGIS	Qgis2threejs, python	Priority queue, Game theory, nash equilibrium, Dijkshtra, dynamic programming	3D

feedback to iteratively improve the design. It will address the challenges of multi-floor navigation and vertical mobility and explore integration with Electronic Health Records (EHR) systems while implementing privacy and security measures. Finally, this research will ensure the scalability and generalizability of the proposed framework.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

JS: Methodology, Supervision, Writing – original draft, Formal analysis. NT: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft. SS: Conceptualization, Investigation, Methodology, Software, Supervision, Writing – original draft. BS: Validation, Visualization, Writing – review & editing. FA: Formal analysis, Project administration, Supervision, Writing – review & editing. AAA: Funding acquisition, Resources, Writing – review & editing. AA: Funding acquisition, Resources, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Sociodemographic factors affecting not receiving COVID-19 vaccine in Japan among people who originally intended to vaccinate: a prospective cohort study

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Objective: Vaccine hesitancy is a major issue for acquiring herd immunity. However, some individuals may go unvaccinated owing to inhibitory factors other than vaccine hesitancy. If there is even a small number of such people, support is needed for equitable vaccine distribution and acquiring herd immunity. We investigated sociodemographic factors that affected not undergoing COVID-19 vaccination in Japan among individuals who had strong intention to vaccinate before beginning the vaccination.

Methods: We conducted this prospective cohort study on workers aged 20–65 years from December 2020 (baseline), to December 2021 using a self-administered questionnaire survey. There were 27,036 participants at baseline and 18,560 at follow-up. We included 6,955 participants who answered yes to this question at baseline: "Would you like to receive a COVID-19 vaccine as soon as it becomes available?" We applied multilevel logistic regression analyses to examine the association between sociodemographic factors and being unvaccinated at follow-up.

Results: In all, 289 participants (4.2%) went unvaccinated. The odds ratios (ORs) for being unvaccinated were significantly higher for participants aged 30–39 and 40–49 than those aged 60–65 years. Being divorced, widowed, or single, having low income, and having COVID-19 infection experience also had higher ORs.

Discussion: We found that some participants who initially had strong intention to vaccinate may have gone unvaccinated owing to vaccine side effects and the financial impact of absenteeism due to side effects. It is necessary to provide information repeatedly about the need for vaccination as well as social support

to ensure that those who intend to vaccinate are able to do so when aiming for acquiring herd immunity through vaccination against COVID-19 as well as other potential infection pandemics in the future.

KEYWORDS

sociodemographic factors, COVID-19, side effects, financial impact, social support, Japan

Introduction

As with many viral infections, vaccination against COVID-19 is the most effective infection control (1). Various types of vaccines for COVID-19, including mRNA vaccines, have been developed over a short period of time and applied worldwide since December 2020 (2, 3). The efficacy and side effects differ according to the type of vaccine; however, many vaccines have been shown both to prevent onset and avert severity and death (4–6).

With an emerging epidemic like COVID-19, a high inoculation rate of effective vaccines can be used to establish herd immunity and control it (7). However, vaccine hesitancy—defined as a "delay in acceptance or refusal of vaccination despite availability of vaccination services"—hinders effective vaccination and poses a major public health issue (8). To reduce such hesitancy for COVID-19 in Japan, educational activities about the significance and risks of vaccination, free vaccination, and fair vaccine distribution began on February 17, 2021 for health-care workers; they were followed by older people and individuals with underlying medical conditions (9). Also, efforts have been made to create convenient vaccination sites and provide vaccines in the workplace (3). By December 2021, the second-dose vaccination among people aged over 12 years had been mostly completed, amounting to 73.4% of the total population (10).

Even though some people initially intended to be vaccinated, they later refuse vaccination owing to some inhibitory factors such as income factors —even though they too initially intended to receive it. If there is even a small number of such people, support is needed for equitable vaccine distribution and acquiring herd immunity. There is a necessity for a prospective cohort study or trajectory study to confirm whether people who initially intended to be vaccinated actually did so; however, few studies have examined the factors that influence vaccination decision. Sigerl et al. investigated COVID-19 vaccination in the United States; they found that 7% of people who were willing to be vaccinated in the baseline survey had become unwilling by the follow-up survey; however, the authors did not confirm actual vaccination rates and did not investigate the related factors (11).

As part of the Collaborative Online Research on Novel-coronavirus and Work (CORoNaWork) study (12), we asked participants about their intention to receive COVID-19 vaccination at baseline and their actual vaccination at follow-up. Using those data, we conducted a trajectory study to examine the sociodemographic factors that affected the actual vaccination rate of individuals who at baseline expressed strong intention to undergo vaccination.

Methods

Study design

We conducted this prospective cohort study as part of the CORoNaWork study. We carried out the baseline survey between December 22 to 25, 2020 and the follow-up survey between December 15 to 22, 2021, by which time the second-dose vaccination had been almost completed in Japan (10). Both surveys were conducted using self-administered questionnaires via the internet. Comprehensive details of the study protocol have been documented elsewhere (12). This study included participants aged 20 to 65 years who were employed at the time of the baseline survey ($n = 33{,}087$). Respondents were sampled taking into account region, occupation, and sex. After excluding 6,051 initial subjects who provided invalid responses, we finally included 27,036 in the database. The criteria of identifying responses as invalid were defined as follows: completion of the survey within a very short time (less than 6 min); body weight significantly below 30 kilograms; height considerably shorter than 140 centimeters; inconsistent responses to similar survey questions; and incorrect answers to a specific question designed to detect unreliable answers.

In all, 18,560 participants (68.6%) undertook the follow-up survey. We conducted our analysis on 6,955 participants who answered yes to this question in the baseline survey, when it was unclear when the vaccination would begin in Japan: "Would you like to receive a COVID-19 vaccine as soon as it becomes available?" Figure 1 is a flow diagram for this study.

This study was approved by the Ethics Committee of the University of Occupational and Environmental Health, Japan (approval numbers: R2-079 and R3-006). Informed consent was obtained on the website from all participants.

COVID-19 vaccination status

We asked participants this question in the follow-up survey: "What is your COVID-19 vaccination status?" Participants chose one of three options: vaccinated twice; vaccinated once; and unvaccinated. We created a binary variable by defining "unvaccinated" as not having received a COVID-19 vaccine and the other options as having the vaccine.

Sociodemographic status

We investigated sex, age, marital status, annual household income, job type, and experience of COVID-19 infection. Age was

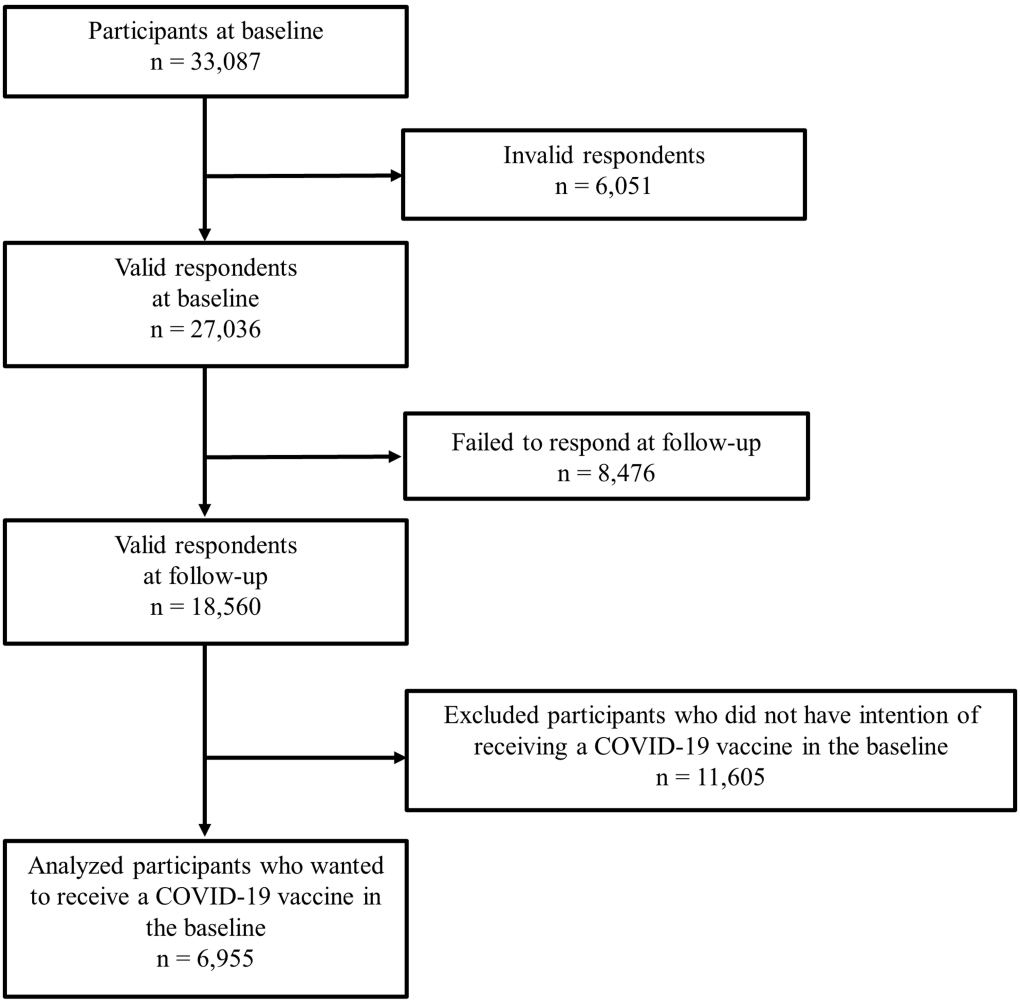

FIGURE 1
Flow diagram of this study.

classified into five groups: 20–29, 30–39, 40–49, 50–59, and 60–65 years. Marital status was classified into three categories: married, divorced or widowed, and single. Annual household income was classified into four groups: <4 million, 4–5.99 million, 6–8.99 million, and ≥9 million yen (US$1 equaled 109.75 yen in 2021) (13). Job type was classified into three categories: mainly desk work, jobs mainly involving interpersonal communication, and mainly physical work. For experience of COVID-19 infection, we asked this question at baseline: "Have you ever been infected with COVID-19?" Respondents answered yes or no. At follow-up, we asked this question: "Have you been diagnosed with COVID-19 since January 2021?" Likewise, respondents answered yes or no. We defined participants who answered yes to either question as having experienced COVID-19.

Statistical analyses

We examined the association between sociodemographic factors and not receiving COVID-19 vaccination among respondents who had originally intended to do so. We estimated age-sex adjusted odds ratios (ORs) and multivariate-adjusted ORs using a multilevel logistic regression model nested in the prefecture of residence to consider regional differences in the infection status of COVID-19. The multivariate model was adjusted for sex, age, marital status, annual household income, job type, and experience of COVID-19 infection. We did not adjust for education because doing so would have been an over-adjustment. We also conducted a trend test with age and annual household income as continuous variables. A p value of less than 0.05 was considered statistically significant. We conducted all analyses using Stata statistical software (release 16; StataCorp LLC, College Station, TX, USA).

Results

The characteristics of the participants appear in Table 1. Of the 6,955 participants analyzed, 4,382 were men (63.0%) and 2,573 women (37.0%). As of December 2021, 289 (4.2%) were unvaccinated.

Table 2 shows the ORs for the association between sociodemographic factors and being unvaccinated among

TABLE 1 Caption.

	N (%)
Number of participants	6,955
Sex	
Men	4,382 (63.0%)
Age (years)	
20–29	276 (4.0%)
30–39	911 (13.1%)
40–49	1,871 (26.9%)
50–59	2,715 (39.0%)
60–65	1,182 (17.0%)
Annual household income (yen)	
<4 million	1,644 (23.6%)
4–5.99 million	1,602 (23.0%)
6–8.99 million	1,936 (27.8%)
≥9 million	1,773 (25.5%)
Marital status	
Married	4,302 (61.9%)
Divorced or widowed	696 (10.0%)
Single	1,957 (28.1%)
Job type	
Mainly desk work	3,492 (50.2%)
Mainly involving interpersonal communication	1,708 (24.6%)
Mainly physical labor	1,755 (25.2%)
Experience of COVID-19 infection	
Yes	152 (2.2%)
COVID-19 vaccination status	
Unvaccinated	289 (4.2%)

participants who originally intended to vaccinate. In the age-sex-adjusted analysis, compared with participants aged 60–65 years, ORs were significantly higher for those aged 20–29 (OR, 2.62), 30–39 (OR, 3.05), 40–49 (OR, 2.03), and 50–59 years (OR, 1.63). Divorced or widowed participants (OR, 2.72) and singles (OR, 2.43) had significantly higher ORs than married individuals. Regarding annual household income, compared with ≥9 million yen, participants with <4 million (OR, 2.46) and 4–5.99 million yen (OR, 1.70) had significantly higher ORs. Mainly physical workers had a higher OR than mainly desk workers (OR, 1.49). Participants with experience of COVID-19 infection had a higher OR than those without experience (OR, 1.85). In the multivariate-adjusted analysis, participants aged 30–39 (OR, 2.46) and 40–49 years (OR, 1.70), divorced or widowed people (OR, 2.25) and singles (OR, 2.04), participants with an income of <4 million yen (OR 1.63), and those with experience of COVID-19 infection (OR, 2.02) had still significantly higher ORs. We also observed a linear relationship between being unvaccinated and age (P for trend = 0.009) and income (P for trend = 0.028).

Discussion

We conducted a trajectory study about COVID-19 vaccination; we examined the sociodemographic factors related to vaccination among participants who at baseline had strong intention to do so. We found that young to middle-aged participants, being divorced, widowed, or single, low-income earners, and individuals with experience of COVID-19 infection were more likely to be unvaccinated. We assumed they became hesitant about vaccination owing to perceived risks associated with vaccine side effects or being unable to receive vaccination for financial reasons.

The reason for becoming hesitant about undergoing vaccination was changing in their risk perceptions related to the vaccines owing to acquiring various information over time. Vaccination decisions are generally influenced by perceptions of two risks: the risk of not being vaccinated (e.g., risk of becoming infected or infection becoming severe); and the risk of vaccination (e.g., vaccine side effects) (14). COVID-19 vaccines were manufactured shortly after the pandemic was declared; that raised overall concerns about side effects and future safety (15). In Japan, two mRNA vaccines, one from Pfizer Inc. and one from Moderna Inc., were used and reportedly caused both local symptoms and systemic symptoms as side effects; those side effects occurred more frequently than with seasonal influenza vaccines (16–19). Thus, we believe those side effects and concerns about vaccine safety owing to the short production time affected the participants' intentions to vaccinate.

Another factor is that employees may have been obliged to be absent from work owing to vaccination side effects and thus went unvaccinated. In Japan, efforts were made to decrease vaccine hesitancy through access issues by ensuring free vaccination, fair vaccine distribution, and convenient vaccination sites (such as workplace vaccination) (3, 9). However, compensation for absenteeism on the day of vaccination and through side effects was determined by companies (3, 20). Therefore, participants who were concerned about vaccination side effects and who were unable or unwilling to take time off work for financial or other reasons may have been less likely to be vaccinated. On the basis of the above two factors, we now discuss each of the study covariates.

We found that younger or middle-aged participants were less likely to be vaccinated than older ones. Younger or middle-aged people were reportedly less likely to be severely infected with COVID-19 than older individuals, which may have reduced infection risk perceptions among the former (21). The Moderna vaccine had a higher rate of systemic side effects, and especially among young men, a higher incidence of myocarditis and pericarditis compared to the Pfizer vaccine (16, 22); however, in Japan, the Pfizer vaccine was mainly used in clinics, whereas the Moderna vaccine was applied in mass vaccination by local governments and in occupational vaccination (23). Accordingly, we observed a higher proportion of young to middle-aged participants who had received the Moderna vaccine. Thus, young to middle-aged participants may have believed that the risk of getting vaccinated outweighed the risks of not doing so.

Among low-income earners, we found that many went unvaccinated even though initially they had intended to be vaccinated. Low-income earners have a high unemployment rate; even during COVID-19, sickness presenteeism was reportedly high (24, 25). It was evidently difficult for such people to take time off work for vaccination. If they did not receive leave compensation for vaccination or its side effects, they may have refused vaccination through concerns about the

TABLE 2 Association between sociodemographic factors and going unvaccinated among participants who originally intended to vaccinate.

	Unvaccinated rate	Age-sex adjusted			Multivariate adjusted*		
	%	OR	95% CI	*p* value	OR	95% CI	*p* value
Sex							
Men	3.8	1.00			1.00		
Women	4.8	1.01	0.78–1.31	0.953	0.84	0.64–1.10	0.199
Age (years)				<0.001†			0.009†
20–29	5.8	2.62	1.35–5.09	0.004	1.88	0.95–3.74	0.071
30–39	6.7	3.05	1.88–4.95	0.000	2.46	1.49–4.04	0.000
40–49	4.5	2.03	1.30–3.18	0.002	1.70	1.08–2.69	0.022
50–59	3.7	1.63	1.06–2.51	0.026	1.51	0.98–2.34	0.064
60–65	2.3	1.00			1.00		
Annual household income (yen)				<0.001†			0.028†
<4 million	6.5	2.46	1.72–3.52	<0.001	1.63	1.11–2.40	0.013
4–5.99 million	4.6	1.70	1.17–2.48	0.006	1.33	0.90–1.96	0.151
6–8.99 million	3.2	1.14	0.77–1.69	0.503	1.04	0.70–1.53	0.858
≥9 million	2.7	1.00			1.00		
Marital status							
Married	2.6	1.00			1.00		
Divorced or widowed	6.5	2.72	1.88–3.92	<0.001	2.25	1.53–3.31	<0.001
Single	6.8	2.43	1.84–3.20	<0.001	2.04	1.52–2.74	<0.001
Job type							
Mainly desk work	3.7	1.00			1.00		
Mainly involving interpersonal communication	3.6	0.92	0.68–1.26	0.612	0.87	0.64–1.20	0.402
Mainly physical labor	5.6	1.49	1.13–1.95	0.004	1.29	0.98–1.71	0.073
Experience of COVID-19 infection							
No	4.1	1.00			1.00		
Yes	7.9	1.85	1.01–3.40	0.046	2.02	1.09–3.72	0.025

*Adjusted for sex, age, marital status, annual household income, job type, and experience of COVID-19 infection.
† *P* for trend.
All analyses used multilevel logistic regression nested in the prefecture of residence.
OR, odds ratio; CI, confidence interval.

direct impact on their incomes owing to taking time off work and even about their employment status as a result of absenteeism. Additionally, individuals who were single, divorced, or widowed, as well as manual workers, were more likely to be unvaccinated, possibly because of their lower incomes (26–28). In particular, manual workers are mainly occupied on-site, making it challenging for them to take time off from work to maintain stable production (25).

With respect to participants with experience of COVID-19 infection going unvaccinated, decreased awareness of the need for vaccination and increased concern about vaccine side effects both possibly had an impact. COVID-19 vaccination is recommended regardless of infection experience, but the reinfection rate reportedly decreases for a while after infection owing to the production of neutralizing antibodies (29, 30). Further, individuals who have been infected are more likely to have vaccine side effects, which may increase their concerns: they may have slowly acquired this information and chose not to receive vaccination (31, 32). Others may have missed the opportunity to be vaccinated because they were infected with COVID-19 shortly beforehand—even though they originally planned to be vaccinated.

We found that a small proportion (4%) of respondents did not receive COVID-19 vaccination despite a strong intention to do so. Sociodemographic factors (such as being young to middle-aged; being single, divorced, or widowed; low-income earners; manual workers; and individuals with experience of COVID-19 infection) may have influenced the vaccination decision. Attribute differences in concerns about vaccine side effects and the impact of side effects on work may also have played a role. Our findings offer suggestions to consider when aiming for acquiring herd immunity through vaccination in future epidemics. First, the national government has to consider

distributing vaccinations by age according to reports of vaccine side effects and consider the type and location of vaccines being more freely selected. Second, it is necessary to explain repeatedly the benefits and needs for vaccination and maintain or enhance the intention to vaccinate. For individuals with infection experience, it is important to provide appropriate information about the following: antibody production due to infection being low compared with the amount of antibody produced by vaccination; the possibility of reinfection; and vaccination being important even after infection owing to the effects of new mutant strains of SARS-CoV-2 (33, 34). Third, it is necessary to consider introducing a direct compensation system for workers and a support system for companies so that employees can take leave owing to vaccine side effects.

This study has several limitations. First, we investigated the reasons for participants going unvaccinated despite initially strongly intending to vaccinate; however, the number of people targeted was small, which may have affected the analysis results. Second, the survey was conducted via the Internet, so there is a limit to its generalizability. Notably, some socially vulnerable groups may have been unable to participate because they lacked Internet access for financial reasons. Third, we did not investigate the exact reasons for going unvaccinated, which we consider to be the most significant limitation of our study. Further research in this regard is required. Fourth, we used responses about infection experience up to December 2021, but we also included in our analysis participants with COVID-19 infection after vaccination; thus, our results may be an underestimate.

In conclusion, we observed that sociodemographic factors (such as being young to middle-aged; being divorced, widowed, or single; having low income; and having COVID-19 infection experience) affect going unvaccinated even if there was initially strong intention to do so. Concerns about vaccine side effects and the impact of side effects on work may have played a role in the vaccination decision. It is necessary to explain repeatedly the need for vaccination and to provide social support to ensure that individuals who intend to vaccinate are able to do so when aiming for acquiring herd immunity through vaccination against COVID-19 as well as other potential infection pandemics in the future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Committee of the University of Occupational and Environmental Health, Japan (approval numbers: R2-079 and R3-006). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AM: Formal analysis, Methodology, Writing – original draft. TM: Formal analysis, Methodology, Writing – review & editing. AO: Data curation, Funding acquisition, Investigation, Writing – review & editing. KMa: Data curation, Investigation, Writing – review & editing. ST: Data curation, Funding acquisition, Investigation, Writing – review & editing. MK: Data curation, Investigation, Writing – review & editing. KMu: Data curation, Funding acquisition, Investigation, Writing – review & editing. YF: Data curation, Funding acquisition, Investigation, Project administration, Supervision, Writing – review & editing. KMo: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The relation between barrier-free environment perception and campus commuting satisfaction

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Introduction: The COVID-19 pandemic, which began in the last quarter of 2019, has had a significant impact on urban transportation. With increasing demand for urban transport, the internal roads and public spaces of university campuses play an important role in facilitating commuting and communication between various functional zones. While considerable research has been conducted on route planning, pedestrian-vehicle segregation, and safety management in the internal transportation environment of university campuses, empirical investigations exploring barrier-free inclusive campus environment design and the subjective evaluation of road and public space users in the aftermath of the COVID-19 pandemic are lacking. Recent developments in travel behavior models and positive psychology have led to an increased focus on the correlation among subjective perceptions, attitudes, emotions, and commuting satisfaction in urban transportation and planning design.

Methods: To elucidate this relationship, a study was conducted on the new campus of Central South University in Changsha, Hunan Province, China. Using 312 valid samples, a structural equation model was constructed to analyse the relationship between commuting satisfaction and the barrier-free environment perception of university students regarding the internal transportation environment of the campus.

Results: The results revealed that individuals' instantaneous barrier-free environment perceptions and long-term established positive emotions had a significant positive effect on commuting satisfaction. Furthermore, positive emotions were found to mediate the relationship between commuting attitudes induced by COVID-19, barrier-free environment perceptions, and commuting satisfaction.

Discussion: The results of this study provide a theoretical basis for the necessity of accessibility design in the post-COVID era. In addition, this study considers the perspective of users to provide ideas for the planning and construction of barrier-free campus environments that are based on convenient and inclusive design.

KEYWORDS

commuting satisfaction, barrier-free environment, positive emotions, university campus commuting, COVID-19, structural equation modelling

1 Introduction

In recent years, interest in the study of mental health and subjective wellbeing has grown (1–3). Consequently, studies on commuting satisfaction have gained attention in the fields of positive psychology and environmentally sustainable development (4). Commuting satisfaction is a unique area within the realm of subjective wellbeing (1, 5); it primarily focuses on factors such as commuting enjoyment (6), commuting stress (7, 8), customer satisfaction with public transport services and passenger perceptions of public transit quality (9), and satisfaction with public transportation and other modes of transport (10, 11). By exploring the relationship between commuting satisfaction and social life participation, the influence of commuting satisfaction on subjective wellbeing can be examined (12). However, the spread of the coronavirus (COVID-19) has exerted a significant influence on public transport travel behaviour (13–16). During severe pandemic lockdowns, university campuses suspended commuting; consequently, college students' mental health has become a prominent focus of research in the post-COVID-19 pandemic era (17–19). Commuting satisfaction is believed to have a positive impact on college students' participation in campus activities and academic success as well as to be beneficial for emotional health (20). Therefore, research on commuting satisfaction can help improve the post-pandemic subjective wellbeing of college students and alleviate their mental health problems.

The construction of barrier-free environments has been demonstrated to play a vital role in improving the quality of cities and the happiness of residents (21). The national "14th Five-Year Plan" in China has explicitly proposed accelerating the improvement of barrier-free engineering and the construction design standard system. Moreover, the Ministry of Education has also stated that the construction of barrier-free campus environments should be promoted at all levels and types of schools (22). The implementation of barrier-free humanised construction in campus spaces should focus on user needs and the current situation. To achieve this, it is important to consider transportation systems and landscape environments. A good campus transportation system is a vital link in realising barrier-free access. Pedestrian–vehicle diversion measures play a variety of roles in ensuring smooth traffic flow and promoting the formation of central pedestrian zones in the campus landscape (23). In addition, green space accessibility within a certain buffer zone has a positive impact on the mental health of college students (24), with the ease of accessibility to green spaces directly affecting college students' perception of the use of the space (25). Barrier-free environments stimulate commuting behaviour by providing user-friendly spaces with high walkability and accessibility (26, 27). Few studies have investigated commuting satisfaction from the perspective of the urban environment. Ye and Ta noted that better-built environments and green spaces can provide improved commuting satisfaction (28–30), while Feng and Dong reported that the higher the accessibility to amenities, public transportation, and green spaces, the more satisfying commuters are with their daily commute (31, 32). Although many studies have discussed the link between urban environments and commuting satisfaction, research addressing the mechanisms responsible for the impact of barrier-free environments on commuting satisfaction is lacking. Some studies have indicated that benign coupling of individual wellbeing with the environment can promote the sustainability of individual health (33). Therefore, this study introduces individuals' momentary perceptions of barrier-free environments, which can provide a deeper understanding of the effect of accessibility on the commuting behaviours and subjective wellbeing of college students. Understanding these effects is essential to promote the efficient construction of barrier-free environments, which can enhance the quality of cities and the happiness of residents in the post-COVID-19 period; this study provides valuable insights to achieve this goal.

Commuting satisfaction is influenced by both commuting attributes and individual subjective factors (34). Commuting satisfaction varies significantly depending on the mode, duration, and purpose of the commute (35–38). However, objective factors such as commuting attributes alone are not sufficient to fully capture the influence of the environment and individuals on determining commuting satisfaction. Although direct questions about travel satisfaction yield a mapping of satisfaction with actual travel attributes, satisfaction ratings may also be influenced by subjective factors such as respondents' attitudes, emotions, and psychological expectations at the time of the interview. It has been shown that commuters' long-term attitudes and pre-existing emotions towards commuting behaviour affect commuting satisfaction both directly and indirectly. A person's attitude towards a particular mode of transportation can directly influence their mood while commuting. For example, those who prefer biking as their mode of transportation are more likely to be happy and satisfied with their commute as opposed to those who resort to biking owing to a lack of alternative options. Additionally, attitudes can indirectly affect travel satisfaction by influencing a person's choice of travel mode (39, 40). For example, commuters who support low-carbon and environmentally friendly travel will be more satisfied with commuting via bicycle or walking (41). Although attitudes are often considered control variables for self-selection, several studies have concluded that attitudes do play a significant role in influencing travel behaviour (42). Positive emotions are considered to be a determinant of subjective wellbeing (43). Ettema et al. (44) reported that positive emotions related to travelling have an impact on subjective wellbeing (34, 44). Chatterjee et al. (45) highlighted the strong connexion between commuting and the overall health of individuals, and found that active commuting modes, such as bicycling or walking, can significantly improve emotional wellbeing (45, 46). Particularly in the context of a pandemic, negative passenger attitudes towards public transport and reduced travel mobility as a result of COVID-19 can have a detrimental impact on the wellbeing of individual public transport commuters. This, in turn, affects physical and mental health, which ultimately leads to a decline in commuting satisfaction (47–51). In addition, the concept of psychological expectations has often been overlooked in studies on commuting satisfaction, with few studies exploring the impact of inconsistencies between actual and desired commuting times on commuting satisfaction (38, 41). The

literature suggests that individual perceptions of environmental stimuli based on individual differences and characteristics, as well as psychological factors, also contribute to the overall assessment of commuting satisfaction in a given environment (3, 52, 53). Interestingly, previous studies have examined a variety of factors that contribute to an individual's satisfaction with their commute. These factors include their perception of the environment, attributes of their commute, attitudes towards commuting, and overall mood. Since the COVID-19 outbreak, several studies have addressed the impact of psychological factors on commuting behaviour under the influence of COVID-19 (13, 54–56). However, only few studies have examined the interrelation and mutual influence of these various factors in the post-COVID era. Research on the connexion between barrier-free campus environments and college students' commute satisfaction has been limited. Therefore, these are important areas for future investigation.

College students' campus involvement has been largely reduced by COVID-19 (57). Students commuting behaviours were limited in most universities to prevent the potential spread of the epidemic (58). Under this circumstance, some university students experience reduced social activities and other troubles, such as financial stresses and academic frustrations, which may cause negative outcomes regarding emotional and perceived satisfaction (59). One study found that most college students felt the pandemic has had a negative impact on their educational experiences (20). After experiencing the COVID-19 lockdown, College students' wellbeing is influenced to a greater extent by the campus environment, and the blockade associated with COVID-19 provides individuals with a new way to perceive the value of campus spaces (60). Their need for barrier-free inclusive campus environment design and use of road and public space has been amplified, which may also have implications for the relationship between barrier-free environment perception, positive emotions, commuting attitudes, and satisfaction. College student populations have unique commuting needs and behavioural choices. Few studies have examined the commuting behaviour of college students. Most of these studies have focused on the choice of commuting mode to and from campus (1, 61), while a few others have explored college students' satisfaction with their campus commutes (20, 62–64). However, empirical investigations exploring barrier-free inclusive campus environment design and the subjective evaluation of road and public space users are lacking, the mechanism by which a perceived barrier-free campus environment affects commuting satisfaction is unclear; this is the main focus of this study. Assessing the commuting satisfaction of college students requires combining individual demographic characteristics, commuting attitudes to COVID-19, positive emotions towards campus commuting behaviours, and momentary perceptions of the barrier-free campus environment. Based on these factors, this study explores the relationship between commuting attitude and commuting satisfaction, as well as the mediating roles of barrier-free environment perception and positive emotion based on positive psychology theories and a model of travel behaviours. The results of this study can provide theoretical references for humanised planning and construction of barrier-free campus environments.

2 Conceptual framework

Subjective wellbeing is a concept that transportation researchers have explored as an alternative to utility when evaluating outcomes for travellers. Several researchers have studied the relation between travel and overall wellbeing. According to Ettema et al. (44) travel affects wellbeing in three ways: it is a means to get to doing activities that impact well-being, the travel experience affects one's experience of the activity that impacts well-being, and the experience of travel in and of itself affects well-being.

The last of these effects – commute wellbeing, also known as commute satisfaction or commute happiness, has been the subject of much research (65). Commute wellbeing relates to the daily commute experience and how it accumulates over time to establish a general level of satisfaction (44). Contributing factors to commute satisfaction include travel distance, time, and cost, as well as travel time variability and many other non-instrumental or "affective" factors that can be referred to as perceived commute quality. Our research focuses in-depth on perceived commute quality.

The concept of barrier-free environment perception involves the psychological relationships between individuals and their surroundings. This theoretical perspective in cultural geography is largely based on self-reported data obtained through interviews or questionnaires, which reflect subjective views of the environment (66, 67). Commuting satisfaction, on the other hand, is a comprehensive evaluation of the transportation service system and the overall commuting experience (45). Research has demonstrated that environmental perceptions can influence satisfaction levels by affecting behavioural intentions. The built environment, particularly its perceived qualities, has a significant impact on walking behaviour. Human behaviour is influenced more by the perceived environment than by the actual environment. Environmental perception focuses on the interactions between individuals and their surroundings in a given environment. Exposure to green spaces while commuting has been found to increase comfort and ultimately improve commuting satisfaction (28). The built environment can indirectly affect commuting satisfaction by influencing commuting behaviours and attributes (68). A barrier-free environment along commuting routes can directly influence individuals' moods and environmental perceptions. Different people may have varying perceptions of the same environment, leading to different satisfaction ratings for the commuting experience.

Emotional responses are the feelings, emotions, etc., that people experience in their daily lives; these comprise a person's emotional wellbeing (46). Emotional responses play a significant role in individuals' overall wellbeing and can affect satisfaction in various aspects of life, including a daily commute. Although objective factors such as commute attributes certainly play a role in satisfaction assessment, subjective factors such as mood and emotions also play significant roles. Research has shown that positive moods can lead to higher levels of satisfaction. Studies in the travel domain have shown that emotions such as enjoyment and stress can affect satisfaction judgments (68). Similarly, factors such as poor weather conditions, bad moods at work, and stressful

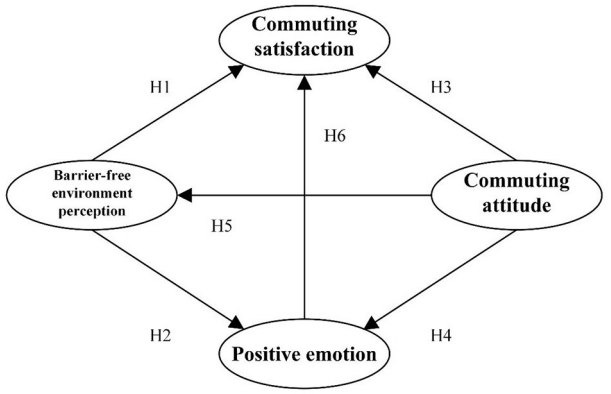

FIGURE 1
Diagram of the conceptual model.

work conditions can also affect commuter satisfaction assessments (69). However, some scholars have discussed the positive impact of moods on commuting satisfaction (70).

Commuting attitudes, i.e., preferences or opinions held by commuters related to commuting behaviour, may affect commuting satisfaction by influencing commuting behaviour. Travel behaviour theories have acknowledged this connexion (71). Commuters tend to have certain expectations regarding their ideal commute; their satisfaction is based on the difference between these expectations and their actual experience (12). For example, according to Huang et al. (72) perceived satisfaction is used to uncover whether the actual appearance and dedicated urban infrastructure (e.g. well-lit urban trails, water fountains, public stretching and exercise equipment, and signage and wayfinding system) correspond with the aspirations and preferences of users. Previous studies have shown that pre-existing attitudes towards a particular commuting mode can affect satisfaction associated with that commute (73). For example, a study on college students found that those who viewed commuting as enjoyable or useful had higher levels of satisfaction, whereas those who only saw it as a means to an end were less satisfied (10). Handy and Thigpen (62) further suggested that using a preferred commuting method may lead to higher levels of satisfaction. Owing to the COVID-19 outbreak, a significant impact on the use of public transportation is expected as commuters may consider the risk of infection (14). Commuting behaviour may be limited owing to emotional, attitudinal, or other psychological factors, and concerns about COVID-19 may overshadow perceptions of commuting satisfaction. Therefore, this study focuses on understanding attitudes towards campus commuting after the pandemic.

3 Hypothetical structure

In this study, we synthesised the results of preliminary research and theoretical models of travel behaviour to construct a conceptual model (see Figure 1). The model proposes a relationship between potential variables and emphasises that an individual's momentary perception of the barrier-free environment may affect their assessment of commuting satisfaction. In addition, long-term attitudes to COVID-19 and positive emotions towards campus commuting behaviours may influence the momentary perception of a barrier-free environment and assessment of commuting satisfaction. Based on this, we formulated eight research hypotheses (from H1 to H8). H1 and H2 considered the relationship between barrier-free environment perception to COVID-19 and commuting behaviour. In public transport, green space exposure was only considered in one study about commute satisfaction (28). Still, its relationship with a barrier-free environment remains to be further verified. H3, H4, H5, and H6 are based on existing literature but will be applied to new data collected after the COVID outbreak, updating the original research in a new context. H7 and H8 considered the mediate effect of positive emotions. Commute satisfaction refers to the satisfaction level of individuals regarding their daily commute to and from campus. This satisfaction can be partially evaluated based on a cognitive assessment of the trip. This definition is in line with the conceptualisation of De Vos and Witlox and builds on the work of Ettema et al. (74) who established cognitive evaluation as a crucial measure of travel satisfaction (5, 74). The attitude towards campus commuting behaviour is a complex multidimensional construct that can be influenced by various factors such as individual characteristics and the environment. However, the measurement of individual attitudes towards campus commuting behaviour is rarely reported in the environmental and planning literature. Emotions, attitudes, or perceived commuting qualities can significantly limit the choice of commuting mode and, therefore, affect satisfaction. Moreover, exploring the correlation between commuter satisfaction and barrier-free environment perception is a critical component of the conceptual model.

4 Methodology

4.1 Study locations

The new campus of Central South University (CSU) in Changsha, Hunan Province, China is situated in a prime location. It is located north of Tuchengtou Road, south of Jinjiang Road, west of Xiaoxiang Avenue, and east of the city's second ring road. The campus is connected to the main campus of CSU in the north, the Shenghua Student Residence Area of CSU in the northeast, the Xiangjiang River Scenic Belt in the east, the University Town Science and Technology Park in the south, and Yuelu Mountain and Houhu Park in the north. The overall layout of the campus is an L-shape (see Figure 2) covering a vast area of 1.41 km^2 as of May 2023. The planning area includes 0.83 km^2 of building areas, including 10 secondary colleges and three secondary teaching and research units. The administrative office of the entire university will also be included. The site has five entrances and exits that allow for convenient transportation via various commuting modes. Additionally, the campus is well-equipped with teaching and public service facilities, providing a conducive environment for students and staff to learn, research, live, and receive services (75).

FIGURE 2
Plan of the study site and photographs of the location.

4.2 Questionnaire design

The questionnaire in this study consisted of five sections. The first section collected demographic information such as gender, age, education level, housing, distance from the residential address to the frequented campus area, purpose of commuting, commuting mode, and commute duration. The second section measured respondents' commuting satisfaction using the Satisfaction of Travel Scale (STS) proposed by Ettema et al. (74, 76), which includes six items centred around emotional experience and cognitive appraisal. The third section used the Warwick Edinburgh Positive Mental Scale (C-WEMWBS) (77) to gauge commuters' positive emotions while commuting on campus. The fourth section focused on collecting information about the respondents' commuting attitudes and preferences in the post-COVID-19 pandemic era (20) based on seven questions aimed at understanding their priorities and motivations when commuting on campus. The fifth section utilised the Perceived Barrier-Free Environment Scale, which was adapted from the well-established scale developed by Liu and Cerin (53, 78) to suit the research scenario. This section was used to measure the perceived level of the overall barrier-free environment of the campus. All questions, except for those in the first section, were based on a Likert-type scale ranging from 1 to 5 (where 1 is strongly disagree, 2 is somewhat disagree, 3 is neither disagree nor agree, 4 is somewhat agree, and 5 is strongly agree).

4.3 Data collection

In April and May 2023, questionnaire data were collected from university students through random sampling. Throughout the survey period, 350 questionnaires were distributed and 320 were returned. Of these, 312 were deemed valid, resulting in a valid questionnaire recovery rate of 89.14%.

TABLE 1 Demographic characteristics of survey respondents ($n = 312$).

Variable	Category	Percentage
Gender	Male	136 (43.6%)
	Female	176 (56.4%)
Age	17–22 years	244 (78.2%)
	23–26 years	58 (18.6%)
	>26 years	10 (3.2%)
Education	Undergraduate	246 (78.8%)
	Masters	55 (17.6%)
	Doctorate	11 (3.5%)
Housing	Dormitory	285 (91.3%)
	Sharing with others	5 (1.6%)
	Renting a room alone	12 (3.8%)
	Living with family	10 (3.2%)

5 Results

5.1 Descriptive statistics

The statistical results indicate that the respondents were equally distributed in terms of gender: 43.6% were men and 56.4% were women. The majority of the respondents were young, with 78.2% falling within the age range of 17–22 years, followed by 18.6% in the age range of 23–26 years. Regarding education, the majority of

TABLE 2 Behavioural factors of survey respondents ($n = 312$).

Variable	Category	Frequency
Distance from residence to frequented campus area, x (km)	$x < 1$	73 (23.4%)
	$1 \leq x < 2$	124 (39.7%)
	$2 \leq x < 3$	79 (25.3%)
	$x \geq 3$	36 (11.5%)
Purpose of this/last campus commute	Attend class	226 (72.4%)
	Self-study	27 (8.7%)
	Exercise	16 (5.1%)
	Leisure	6 (1.9%)
	Work or administrative affairs	30 (9.6%)
	Other	7 (2.2%)
Mode of transportation for this/last on-campus commute	Walking	76 (24.4%)
	Bicycle	53 (17.0%)
	Electric bicycle or motorcycle	157 (50.3%)
	School bus	11 (3.5%)
	Private car	10 (3.2%)
	Taxi or internet taxi	5 (1.6%)
Length of transportation for this/last campus commute (min)	<15	230 (73.7%)
	15–45	74 (23.7%)
	>45	8 (2.6%)

the respondents were undergraduates (78.8%), followed by 17.6% with master's degrees and 3.5% with doctoral degrees. The majority of respondents lived in shared quarters (91.6%). Based on these demographic characteristics, the sample was well-represented and could meet the data requirements for further empirical research (see Table 1).

Table 2 presents data on the behavioural variables of the respondents. The statistics reveal that 40% of the respondents commuted within a distance of 1–2 km. In addition, 72.4% of the respondents commuted to attend classes. More than 50% of the respondents used electric bicycles or motorcycles as their mode of transportation, and over 70% reported a commute time of <15 min.

5.2 Commuting attributes, barrier-free environment perception, and commuting satisfaction

Figure 3 shows variations in the commuting satisfaction and barrier-free environment perception based on different factors, such as the commuting distance, purpose, mode, and duration. The results indicate that the perception levels were influenced by the commuting distance, with the highest perceived level reported for distances ≥3 km. Commuting for sports and leisure resulted in the highest barrier-free environment perception level. Among the different modes of commuting, bicycling yielded the highest perceived level, whereas taking a taxi or internet taxi produced the lowest perception of a barrier-free environment. The commute duration had an average perception level showing a U-shaped pattern, with college students having the lowest perception of a barrier-free environment during a 15–45 min commute. Based on these results, it can be inferred that college students may take different routes during their campus commutes, leading to differing levels of barrier-free environment perception.

Figure 3 shows the average satisfaction levels for different commuting attributes. The results indicate that commutes under 1 km produced the highest satisfaction levels, possibly because of the availability of walking and bicycling as convenient options for short commutes, which provide exercise and allow for campus exploration. The respondents also showed higher satisfaction when commuting actively for exercise and self-study. Private cars, walking, and bicycling were also highly satisfactory modes of transportation, likely because they are predictable, typically used for short commutes, and carry less risk of infection than public transportation. Longer commutes (over 45 min) were found to be the most satisfactory, followed by commutes under 15 min. Medium-to-long commutes showed lower levels of satisfaction, which is consistent with the perceived level of the barrier-free environment. These findings suggest a complex relationship between perceptions of a barrier-free environment and commuting satisfaction, requiring further investigation.

5.3 Reliability and validity analysis

A reliability test was conducted on the measurement model based on valid data collected from the questionnaires. The results showed that the Cronbach's alpha values of the four latent variables (commuting satisfaction, barrier-free environment perception, commuting attitude, and positive emotions) ranged from 0.885 to 0.951, indicating strong internal reliability (see Table 3). The overall Cronbach's alpha value of the scale was 0.942 (>0.700), and the Kaiser–Meyer–Olkin (KOM) sampling fitness number was 0.926 (>0.700). The significance of the Bartlett's sphericity test was 0.000 (<0.001), indicating that the data were suitable for exploratory factor analysis.

Confirmatory factor analysis was then conducted to validate the results. The standardised factor loading values for each question item under each latent variable were greater than the minimum threshold criterion requirement of 0.500, while the construct reliability (CR) values of each latent variable were >0.900 (>0.700). The average variance extracted (AVE) values of each latent variable were also greater than the minimum threshold criterion requirement of 0.500, indicating good reliability and validity of each latent variable in the scale (see Table 3).

To determine the discriminant validity of the latent variables, their correlation coefficients were compared with the square root of the AVE of each latent variable. The results showed that the correlation coefficients for each latent variable with the other latent

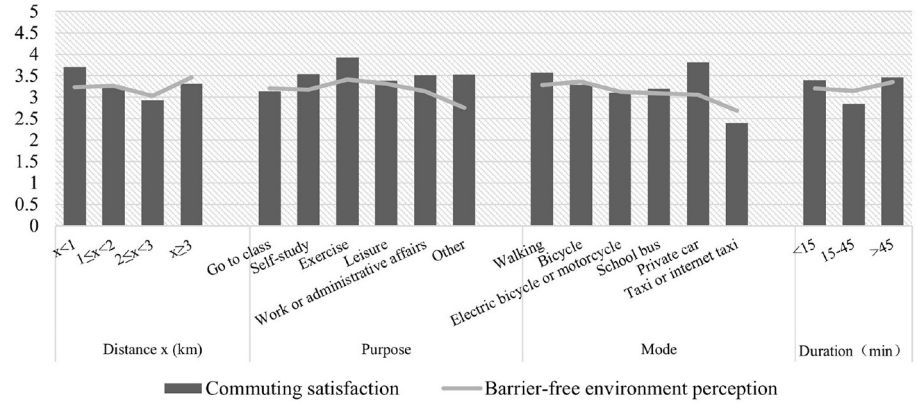

FIGURE 3
Average levels of barrier-free environment perception and commuting satisfaction for different commuting attributes.

variables were smaller than the square root of the AVE of each latent variable, indicating good validity of the scale data.

5.4 Structural equation model analysis

5.4.1 Structural equation model goodness-of-fit analysis

The model parameters were estimated using the maximum likelihood method. The analysis of the overall goodness-of-fit of the model shows (see Table 4) that all of the indexes met the test criteria. Therefore, the model fit was good, and the results were acceptable.

5.4.2 Hypothesis testing results

The test criterion for path analysis was set at a significance level of $p < 0.050$. We analysed the results of the measurement model (see Table 5) and found that the standardised factor loadings between the latent variables and corresponding observational variables were >0.5. We also conducted a hypothesis test (see Table 6 and Figure 4) and found that hypotheses H1, H2, H3, and H6 were valid, whereas hypotheses H4 and H5 were not. Based on these results, we revised the theoretical model by eliminating the paths that did not pass the hypothesis test, resulting in the revised model (see Figure 5).

5.4.3 Results of mediation effect testing

We used the bootstrap method to evaluate the mediation effect and estimated it based on a bias-corrected interval. If the 95% confidence interval (95% CI) for the indirect effect does not encompass zero, it indicates a statistically significant mediation effect. The model yielded direct, total, and indirect effects (see Table 7).

Based on the results of the mediation analysis, the CI for the "commuting attitude - barrier-free environment perception - positive emotion" mediating effect is (−0.110, 0.114), which includes zero, thus suggesting a non-significant mediation effect in this pathway. However, none of the CI values for "commuting attitude - positive emotion - commuting satisfaction" or "barrier-free environment perception - positive emotion - commuting satisfaction" include zero, indicating significant mediating effects in these paths. Moreover, the direct impact of commuting attitude on commuting satisfaction is observed to be statistically significant, highlighting that positive emotions fully mediate between commuting attitude and commuting satisfaction, while positive emotions partially mediate the connexion between barrier-free environment perception and commuting satisfaction.

6 Discussion and conclusion

We investigated the relationship between momentary perceptions of barrier-free campus environment stimuli and the commuting satisfaction of college students in the post-COVID-19 pandemic era using data from the new CSU campus. The results are expected to enhance our understanding of barrier-free campus environment perceptions and the level of satisfaction with college students' commuting experiences.

6.1 Influence of barrier-free environment perception on commuting satisfaction

It has been generally documented that a good perception of environmental features is associated with higher commuting satisfaction (29, 72). Consistent with this, we found that barrier-free environment perception was positively associated with commuting satisfaction (79). We propose a barrier-free environment as a built environment feature from the perspective of users' subjective evaluation. SEM was used to further explore the path relationships and mediating effects that exist between barrier-free environment perception, commuting satisfaction, positive emotions, and attitudes among college students. The effect of barrier-free environment perception on commuting satisfaction has a simple path of "barrier-free environment perception - commuting

TABLE 3 Fitting factors for measurement scale problems.

Structure variables	Code	Source of observation indicators	Standardised factor loadings	Cronbach's alpha value	CR	AVE
Commuting satisfaction (CS)	CS01	Time elapsed during this/last campus commute	0.853	0.936	0.929	0.686
	CS02	Fatigue level during this/last campus commute	0.857			
	CS03	Level of boredom during this/the most recent campus commute	0.814			
	CS04	Level of service during this/the most recent campus commute	0.753			
	CS05	Convenience of commuting to campus this time/last time	0.843			
	CS06	Overall efficiency of the commute this time/last time	0.845			
Positive emotion (PE)	PE01	I have always felt optimistic about the future	0.749	0.951	0.946	0.556
	PE02	I have always felt useful	0.785			
	PE03	I have always felt relaxed	0.730			
	PE04	I am always open to making new friends	0.718			
	PE05	I have always had a lot of energy	0.828			
	PE06	I have been able to solve problems well	0.819			
	PE07	I have been able to think clearly	0.802			
	PE08	I am always satisfied with myself	0.815			
	PE09	I always feel good about my relationships with others	0.735			
	PE10	I am always confident	0.751			
	PE11	I have been able to make my own decisions	0.700			
	PE12	I have always felt loved by others	0.634			
	PE13	I am always interested in new things	0.646			
	PE14	I am always in a good mood	0.693			
Barrier-free environment perception (BEP)	BEP01	I can easily find accessible facilities (e.g. blind alleys, accessible elevators, etc.) and accessible services (e.g. Braille signs, audio announcements, etc.) on campus	0.757	0.921	0.916	0.645
	BEP02	I am very satisfied with the lighting conditions in pathways, corridors, and stairways on campus	0.762			
	BEP03	The existence of curbed ramps, blind alleys, barrier-free access, Braille signage, and other barrier-free facilities on campus makes my commute more comfortable and convenient	0.799			

(Continued)

TABLE 3 (Continued)

Structure variables	Code	Source of observation indicators	Standardised factor loadings	Cronbach's alpha value	CR	AVE
	BEP04	I think the overall accessibility of the campus is very good	0.870			
	BEP05	I think the number of barrier-free facilities and services on campus is sufficient	0.870			
	BEP06	I think the campus has good accessibility to all functional areas	0.750			
Commuting attitude (CA)	CA01	It is important to get to my destination as quickly as possible after the epidemic	0.719	0.885	0.900	0.566
	CA02	Flexibility in commuting time is important after the epidemic	0.832			
	CA03	Predictability of the length of the commute is important after the epidemic	0.786			
	CA04	Getting to my destination by the cheapest mode of transportation is important after the epidemic	0.738			
	CA05	Environmentally friendly travel is important after the epidemic	0.602			
	CA06	Minimising commuting in rain or snow is important after the epidemic	0.789			
	CA07	Minimising commuting in very hot or very cold weather is important after the epidemic	0.777			

satisfaction" and a complex path of "barrier-free environment perception - positive emotion - commuting satisfaction" (80). The results of this study reveal that an individual's assessment of commuting and environmental satisfaction is mainly based on their perception of the barrier-free environment, physical activity, and social interaction during commuting. This includes direct satisfaction through the psycho-neurological pathway and indirect satisfaction through the corresponding emotional satisfaction pathway. A rich perception of a barrier-free environment may give students a positive psychological perception of a campus with perfect humanised construction. Positive psychology can stimulate individuals' emotional mechanisms and mobilise positive emotions to yield better commuting satisfaction.

Participating in educational, social, and extra-curricular activities on campus can have a positive impact on the emotional wellbeing of college students. In addition to this, easy physical access to these opportunities can further enhance the frequency and quality of these experiences. A barrier-free environment can also facilitate these educational and social encounters, making them more accessible to a wider range of students (20, 81). The internal roads, public spaces, and building facilities of a university campus together constitute the overall barrier-free environment of the campus. They allow for easy commuting and communication between different functional areas on campus. The planning and design of internal campus roads and public spaces is based on the campus's functional zoning, which helps realise the transportation grid (82). Proper planning can enhance the connectivity of various functional areas such as the teaching, college, and living areas. This, in turn, helps students move seamlessly through different areas. It is easier for students to cross paths with one another, thus increasing the possibility of collegiality and interdisciplinary dialogue and enhancing campus vitality (83). To support student wellbeing during a pandemic, academic institutions must create an inclusive and accessible campus environment where students are more likely to reach their full potential.

TABLE 4 Structural equation model fit indices.

Criterion	CFI	TLI	RMSEA	χ^2/df
Value	0.930	0.923	0.061	2.149

TABLE 5 Results of the measurement model.

Structure variables	Observation indicators	Standardised path coefficient	*p*-value
Commuting satisfaction	CS01	0.814	***
	CS02	0.795	***
	CS03	0.773	***
	CS04	0.831	***
	CS05	0.881	***
	CS06	0.873	***
Positive emotion	PE01	0.791	***
	PE02	0.788	***
	PE03	0.759	***
	PE04	0.711	***
	PE05	0.844	***
	PE06	0.831	***
	PE07	0.810	***
	PE08	0.823	***
	PE09	0.792	***
	PE10	0.769	***
	PE11	0.696	***
	PE12	0.669	***
	PE13	0.684	***
	PE14	0.722	***
Barrier-free environment perception	BEP01	0.705	***
	BEP02	0.765	***
	BEP03	0.770	***
	BEP04	0.907	***
	BEP05	0.909	***
	BEP06	0.816	***
Commuting attitude	CA01	0.726	***
	CA02	0.857	***
	CA03	0.796	***
	CA04	0.743	***
	CA05	0.577	***
	CA06	0.642	***
	CA07	0.637	***

***$p \leq 0.01$.

6.2 Influence of commuting attitude and positive emotion on commuting satisfaction

Based on the model path coefficients, subjective emotions have a greater direct effect on commuting satisfaction than environmental perceptions. Positive emotions have a significant positive effect on commuting satisfaction. College students' long-term positive emotions contribute to their subjective interactions and connexions with barrier-free environments. This leads to a higher sense of wellbeing in the environment and positively affects their instantaneous commuting satisfaction. In addition, long-term attitudes to COVID-19 do not have a significant effect on commuting satisfaction, which differs from most studies that have found that commuting-related attitudes and preferences have direct and indirect effects on commuting satisfaction (29, 78, 84). This difference may have occurred because since the COVID-19 pandemic has ended, the epidemic policy has changed.

TABLE 6 Results of the structural model.

Hypothesis	Connexion	Standardised path coefficient	*t*-value	*p*-value
H1	Barrier-free environment perception → commuting satisfaction	0.277	5.344	0.000
H2	Barrier-free environment perception → positive emotion	0.442	7.288	0.000
H3	Commuting attitude → positive emotion	0.376	6.212	0.000
H4	Commuting attitude → commuting satisfaction	−0.123	−0.695	0.487
H5	Commuting attitude → Barrier-free environment perception	0.166	1.628	0.104
H6	Positive emotion → commuting satisfaction	0.423	4.670	0.000

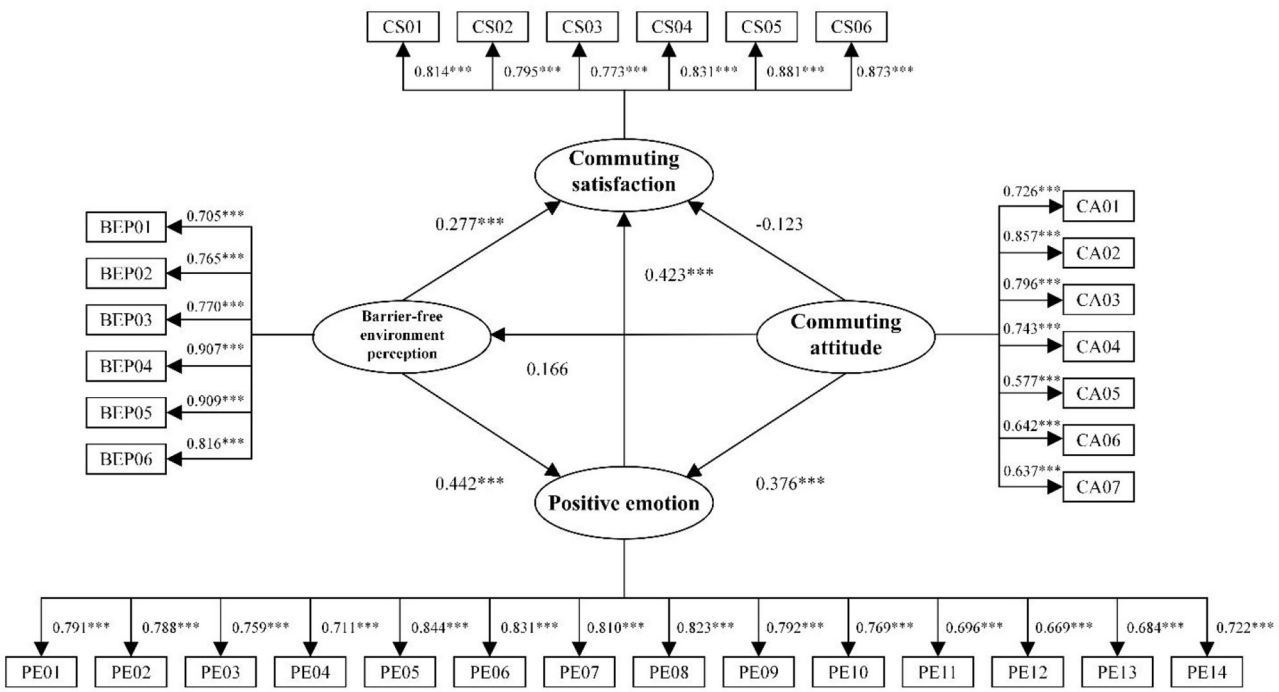

FIGURE 4
Estimated road map of the standardised parameters of the model. ***$p \leq 0.01$.

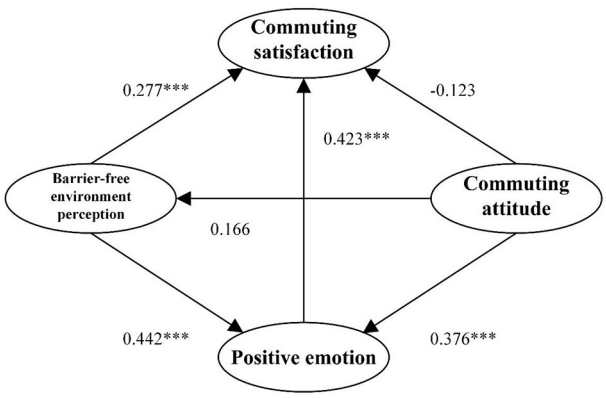

FIGURE 5
Modified theoretical model. ***p ≤ 0.01.

Some of the previously mentioned psychological factors that produce changes due to the risk of infection no longer pose a threat to commuting behaviours. The current study was conducted at only one university, where the student population may have more homogeneous commuting behaviours and no clear preference for prioritising commuting behaviour choices. Students' attitudes and preferences towards commuting may also have been affected by the limitations of the weather conditions in Changsha in May and June and the current status of transportation organisations on campus. Individual adaptation or aesthetic fatigue to the geographic environment may also explain this difference (28). Because attitudes and preferences are formed based on an individual's long-term experience, the campus commuting behaviour of the college student population may be a single journey day after day, and such repetitive journeys may affect students' attitudes and preferences related to campus commuting. Therefore,

TABLE 7 Mediation effect results.

	Mediation path	Indirect effect coefficient	*p*-value (two-tailed)	95% CI		Estimate
				Lower	Upper	
H7	Barrier-free environment perception - positive emotion - commuting satisfaction	0.145***	0.000	0.070	0.247	Valid
H8	Commuting attitude - positive emotion - commuting satisfaction	0.252***	0.001	0.118	0.426	Valid
	Commuting attitude - barrier-free environment perception - positive emotion	0.046*	0.102	−0.110	0.114	Invalid

***$p \leq 0.01$, *$0.05 < p \leq 0.1$.

the effects of short- and long-term journeys on commuting satisfaction require further investigation. However, commuting attitudes indirectly affect commuting satisfaction through positive emotions, and the respondents' commuting attitudes had a significant positive effect on positive emotions. Respondents' preferred commuting behaviours imply better positive emotions, which in turn provide higher commuting satisfaction. This study shows that, in the post-COVID-19 pandemic era, attitudinal preferences for positive emotions towards commuting behaviours are focused on the importance of commuting efficiency (e.g. "Getting to my destination as soon as possible is important after the epidemic", "Flexibility in commuting time is important after the epidemic", "Predictability of commute time is important after the epidemic", and "Getting to the destination by the cheapest mode of travel is important after the epidemic").

Previous studies have explored the connexion between commuting satisfaction and all three individual demographic characteristics as well as psychological and behavioural factors (1, 28, 38, 45, 73). However, this study is the first to confirm the indirect and direct effects of long-term attitudes, positive emotions, and momentary environmental perceptions related to commuting on commute satisfaction. The results suggest that satisfaction assessment depends on perceptions based on momentary conditions related to places and people as well as long-term subjective attitudes based on experiences and perceptions. Overall, this study provides valuable insights for promoting humanised planning and the construction of campus commuting and barrier-free environments for college students in the post-COVID era.

7 Limitations and outlook

We acknowledge that this study has some limitations. First, the assessment of campus commuting satisfaction was based on individual differences, perceptions of environmental stimuli, and psychological and behavioural factors. However, it did not consider the effect of demographic characteristics on the perception of commuting satisfaction among public transportation users. Future studies should consider demographic characteristics in order to reveal the heterogeneity of perceptions. Second, the objectivity of the indicators may have been influenced by respondents' underestimation or overestimation of their psychological responses. This study also ignored the effects of active and passive travel on college students' psychological factors. Future studies should include physiological indicators to improve measurement accuracy. Finally, the study sample consisted only of college students, and future studies should expand the sample type and collect more field data from a wider range of public transportation routes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the current study in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

JL: Conceptualization, Resources, Supervision, Writing – original draft. CZ: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft. XC: Conceptualization, Resources, Writing – review & editing. YP: Conceptualization, Methodology, Writing – review & editing. SL: Supervision, Writing – review & editing. WL: Formal analysis, Investigation, Resources, Writing – review & editing. YC: Formal analysis, Investigation, Writing – review & editing. YL: Formal analysis, Investigation, Writing – review & editing. LY: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling editor WR declared a shared affiliation with the authors JL, CZ, SL, YC, and YL at the time of review.

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Public mental health through social media in the post COVID-19 era

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Social media is a powerful communication tool and a reflection of our digital environment. Social media acted as an augmenter and influencer during and after COVID-19. Many of the people sharing social media posts were not actually aware of their mental health status. This situation warrants to automate the detection of mental disorders. This paper presents a methodology for the detection of mental disorders using micro facial expressions. Micro-expressions are momentary, involuntary facial expressions that can be indicative of deeper feelings and mental states. Nevertheless, manually detecting and interpreting micro-expressions can be rather challenging. A deep learning HybridMicroNet model, based on convolution neural networks, is proposed for emotion recognition from micro-expressions. Further, a case study for the detection of mental health has been undertaken. The findings demonstrated that the proposed model achieved a high accuracy when attempting to diagnose mental health disorders based on micro-expressions. The attained accuracy on the CASME dataset was 99.08%, whereas the accuracy that was achieved on SAMM dataset was 97.62%. Based on these findings, deep learning may prove to be an effective method for diagnosing mental health conditions by analyzing micro-expressions.

KEYWORDS

public mental health, individual behavior, micro-expressions, COVID-19, social media, CNN

1 Introduction

The interconnectedness of individual behavior, the environment, COVID-19, and social media has significantly shaped the global community during the COVID-19 pandemic. As a powerful communication tool and a reflection of our digital environment, social media acted as an augmenter and influencer during and after COVID-19. Social media platforms have become primary sources of information about COVID-19. Social media platforms primarily share news, updates, and expert opinions. The rapid spread of information on social media has resulted in the promulgation of misinformation, conspiracy theories, and false claims about COVID-19.

Social media served as a platform for sharing images, videos, and stories related to the pandemic. These visuals spread awareness about the environmental impact of the virus, including healthcare systems working beyond their capacities and shortages of medical supplies. Social media was instrumental in organizing community efforts during the pandemic, ranging

from neighborhood support groups to initiatives for assisting vulnerable populations (1). Social media provides a direct channel for government agencies and public health organizations to communicate with the public and offers spaces for sharing personal experiences and seeking emotional support. The pandemic has taken a toll on mental health, and social media has played a role in exacerbating stress and offering a platform for coping mechanisms. Social media platforms have also been responsible for creating echo chambers where individuals are exposed only to information that aligns with their preexisting beliefs. Excessive use of social media can contribute to mental health issues, such as anxiety, depression, and social isolation (2, 3). The constant streaming of pandemic-related news on social media can lead to information overload and increased stress. It may influence individual behavior and mental health. Understanding the interconnectedness of individual behavior, the environment, COVID-19, and social media is critical for policymakers, public health officials, and researchers. It underscores the importance of managing information dissemination, addressing misinformation, and leveraging social media to promote positive behaviors and community resilience. Moreover, it highlights the need for a holistic approach to public health that considers the digital environment an integral part of the broader ecosystem in which health crises unfold (4, 5).

The transformations occurring within the broader community have played a substantial role in escalating mental health issues and behavioral disorders. The World Health Organization (WHO) has defined "mental health" as the state of an individual who can effectively manage their life stressors within their capabilities while simultaneously maintaining optimal functioning in their occupational pursuits and making meaningful contributions to society (6). Various elements that impact mental health likely emanate from an individual's lifestyle, encompassing work-related stress, unfavorable financial circumstances, familial challenges, interpersonal difficulties, and exposure to violence. Additionally, environmental factors may also contribute to these effects (7). Mental health is becoming an enormous global issue, considering the millions of individuals affected by mental illnesses, including stress, anxiety, Post-Traumatic Stress Disorder (PTSD), and depression (8). Many people remain unidentified or unattended, even though early identification and assistance are essential for the optimal treatment and supervision of such disorders. Conventional techniques for identifying mental health issues, such as clinical investigations, self-report questionnaires, psychological evaluations, and professional interviews, can be biased, costly, and time-consuming. These methods might not be accurate or dependable, particularly for those unwilling to express their genuine emotions (9). Since emotions are a fundamental part of human interaction, they can significantly impact mental illnesses in the context of human behavior, responses, and perspectives. Anger, disgust, sadness, and fear are some negative emotions that people with mental conditions may encounter. Such emotions can be intense and persistent, making it challenging for the individual experiencing them to carry on with their regular activities (10). Over the conventional techniques, however, there has been a dearth of appropriately trained mental health specialists, and the stigma prevents many people from seeking assistance. However, concerning the traditional methods for diagnosing mental disorders, there is a shortage of adequately trained mental health specialists, and the stigma keeps many people from getting help (11).

Alternatively, new approaches to the large-scale identification and understanding of emotions and mental health conditions have been made possible by recent developments in computer vision, affective computing, human-computer interaction, machine learning, and information analytics techniques. Machine learning techniques are fully dependent on training and testing data, which can be collected through Internet of Things (IoT) devices, social media networking sites, physiological signals, facial expressions, speech, and text (12–14). Social networking platforms such as YouTube, Twitter, Facebook, Sina Weibo, Instagram, and Reddit that allow users to express their thoughts and emotions are becoming more and more popular. Social media platforms allow users to express their emotions and thoughts by sharing various forms of data, including text, photographs, audio, and videos, pertaining to their everyday experiences. Millions of individuals worldwide daily utilize these social networking platforms. Various forms of data, including text, photos, video, and audio, convey feelings and thoughts through online postings. These applications generate a substantial amount of data. This overabundance of data results from a growth in communication, and these massive amounts of data have become content producers that could be helpful for additional research and analysis. As a result, it can be utilized to create a method for identifying mental health issues. The analysis of facial expressions and their correlation with personal conceptions is a pertinent issue in social media, as facial expressions have been significant indicators of various psychological characteristics in human beings (15).

Facial micro-expression analysis has gained popularity in identifying mental health issues in recent years. Microexpressions are quick, uncontrollable facial gestures that convey a person's subconscious feelings. They seem to be a potentially helpful tool for mental health detection because they are hard to manipulate or fabricate (16, 17).

The researchers have created machine-learning models that can identify microexpressions linked to sadness, anxiety, and depression with a high degree of precision. These models can be applied to developing novel diagnostic frameworks for the early identification and treatment of mental health issues. Additionally, new diagnostic instruments for mental health practitioners could be developed by employing deep learning models. For instance, a model might be used to interpret a patient's facial expressions during a clinical interview to assist the physician in diagnosing the patient (15, 17–19). Microexpressions are unintentionally reflected expressions that cannot be seen through the naked eye as compared to macroexpressions. Micro-expressions can be captured through a high-resolution camera (20). The proposed study presents a framework for analyzing the facial micro-expressions in video frames of people with mental disorders and healthy controls by analyzing their social media videos.

The structure of this document is as follows: Section 2 includes related work, Section 3 contains information on the collection and pre-processing of the data and proposed Hy-bridMicroNet model used for emotion recognition, Section 4 presents the experimental work along with results and discussion, Section 5 embodies the case study and Section 6 provides the conclusion and future scope.

2 Literature review

The integration of micro-expressions for the identification of mental health illnesses has become an important subject in computer

science and psychology. A summary of significant studies and developments in the field of micro-expressions based mental health detection is given in this related work section. Paul Ekman's research on micro-expressions, which reveal concealed emotions and emotional disorders, has paved the way for the potential use of these expressions for mental health assessment (21).

Researchers investigated into using micro-expressions as a technique to detect depression, which is among the most common mental health disorders. Facial dynamics, vocal parodies and head motions were employed in clinical interviews and interpersonal settings to determine the level of depression that was identified in the research study. In all, 57 patients with depression were asked to take part in the investigation, and the Hamilton depression rating scale was used to conduct their assessments. Using Z-Face technology, 3D registration from the 2D video is accomplished in this work. Stack Denoising Auto-encoders (SDAE) are then employed to encode the head and face movements by mapping features and enhancing fisher vector coding. This research has a 78.67% accuracy rate (22).

Beck Depression Inventory (BDI) score estimation used for feature analysis of facial expressions, employed for automatic depression detection. Macro-structure and Micro-structure of facial dynamics features were extracted through Median Robust Local Binary Patterns from three orthogonal Planes (MRLBP-OP). The MRLBP-Top across an image succession was also suggested to be aggregated using Dirichlet Process Fisher Encoding (DPFP). The assessments and evaluations were conducted using the depression datasets AVEC-2013 and AVEC-2014. According to the Mean Absolute Error (MAE) of 7.55 and the Root Mean Square Error (RMSE) of 9.20, the findings were assessed (23).

In a subsequent study, BDI was used to detect depression levels employing the video data. Recurrent neural networks and 3D convolution neural networks (RNNsC3D) were applied in the proposed framework for automatically learning the spatiotemporal characteristics of the facial region. AVEC-2013 and AVEC-2014 depression datasets were used for the experiments. The findings that were obtained have been assessed using the RMSE with 9.28 and MAE with 7.37 (24).

A deeper and naive model was proposed to classify and quantify depression based on textual and visual descriptions. Text and audio-visual features were extracted using Support Vector Machine (SVM), and a deep Convolutional Neural Network (CNN) for evaluation of physical and mental health of the individual. Random Forest (RF) was applied to classify the depression utilizing the inputs from SVM and CNN. The research findings obtained using AVEC-2016 dataset, having a the F1 score of 0.746 (25).

Multimodal Attention Feature Fusion (MAFF) and Spatiotemporal Attention Network (STA) techniques-based model was proposed for depression detection and prediction. Audio analysis was performed by dividing the voice frequency into fixed length segments and subsequently inserting these segments to a STA network to integrate temporal and spatial data. This framework applied the eigen evolution pooling technique to evaluate the alterations in every dimension associated with the audio-visual segmentation feature. Additionally, Support Vector Regression (SVR) was employed for processing the MAFF. The experimentation yielded an RMSE of 8.16 and an MAE of 6.14 using the AVEC2013 and AVEC2014 datasets (26).

Automatically detection of severity signs of anxiety and depression were measured by proposed SVM model through features extraction techniques such as Local Binary Patterns (LBP), Histogram of Oriented Gradients (HOG), and Visual Geometry Group (VGG) from a video dataset. BDI-II and State–Trait Anxiety Inventory (STAI) scores were calculated in terms of normalized RSME (16.73, 12.42) and MAE (12.48, 9.85). The suggested approach was assessed using LeaveOne-Subject-Out (LOSO) cross-validation technique. This procedure can be repeated as per number of subjects in the dataset rather than sample collection. Gender-dependent and gender-independent cross-validation were executed out independently. The framework was trained and tested using attributes generated from either female or male subjects in the gender-dependent strategy. Findings shows that VGG-19 feature extraction technique was outperformed to detect depression and HOG also performed better in another setups. The results obtained from current dataset (depressed-20 and healthy controls-45) were compared with AVEC2014 dataset (16).

An Enriched Long-term Recurrent Convolutional Network (ELRCN) was proposed for emotion recognition through facial micro-expressions. The model has two variants for spatial feature extraction and temporal dynamics characterization named Spatial Dimension Enrichment (SE) and Temporal dimension Enrichment (TE). Large data input used for SE by stacking the optical flow, optical strain, and gray-scale images. VGG-16 model used for training the model and ending fully connected layer encoded the data into fixed-length vector. VGG-Face model used for TE for transfer learning of pre-trained weights. Both variants used Long Short-Term Memory (LSTM) algorithm for temporal learning. The Chinese Academy of Sciences Micro-expression (CASME-II) and Spontaneous Micro-Facial Movement Dataset (SAMM) datasets were used for experiment to obtain F1-score, accuracy in Weighted Average Recall (WAR) and Unweighted Average Accuracy (UAR). LOSO methodology was used for training since it minimizes subject bias in the learning process (27).

A framework for detection of Autism Spectrum Disorder (ASD) based on micro-expressions was developed using computer vision techniques. Facial Action Coding System (FACS) was used for facial micro-movements analysis. FACS contains a comprehensive set of features labeled as Action Units (AUs) that depict the individual parts of face, enabling the decoding and measurement of every potential expression due to contraction of the facial underlying muscles. This study specifically focused on positive facial expressions "smile" (connected with AU12) particularly Social Smile that can be identified by extra activation of AU06. Multivariate Analysis of Variance (MANOVA) was used to test for statistically significant differentiation between ASD and Typically Developed (TD) groups. The results indicated that statistically substantial variations between the Typically Developed (TD) and ASD groups for descriptive variables such age, gender, and home video characteristics in case of social smile (28).

To identify the older adult depression an investigation was conducted based on facial micro-expressions recognition from the video dataset of 100 older adult subjects (50 – depressed, 50 – healthy controls). The video frames were processed into an optical flow image that reflects the variations in micro-expressions. Due to rapid changes with low amplitude of micro-expressions, a jump connection VGG-16 model was employed for feature fusion on the outcomes of 3–5 blocks of convolutional layers. To identify the older adult depressive people's microexpressions, the merged results were placed into a fully-connected layer. Mean recall and F1-score were measured for evaluation of model performance on CASME, SMIC, SFEW and VAM

corpus datasets. The results demonstrate that older adult depressed individuals, regardless of gender, showed a significant difference in the occurrences of negative as well as positive expressions for each level when compared to normal people. This supports the theory that older people who are depressed respond less strongly to happy emotions and more strongly to negative ones (29).

A CNN-based method was presented to identify Major Depressive Disorder (MDD) by predicting emotion from the facial expressions of 12 subjects in YouTube interview videos. The VGG16 model was used to perform facial recognition on extracted frames, which were obtained every 0.2 s. During the data pre-processing stage, multiple faces or frames with no faces were eliminated. Using Openface and VGG19, respectively, several AUs and emotional characteristics were retrieved. SVM, LR and gradient boosted decision tree algorithm were used for classification of seven emotions. A leave-one-subject-out cross-validation approach was employed to achieve an Area Under the Curve (AUC) of 0.72 for remission categorization and 0.75 for response to therapy (30).

The COVID-19 epidemic has resulted in a surge in social media utilization, as individuals increasingly depend on digital platforms to access health-related information. Based on a comprehensive analysis of existing literature, it has been determined that heightened exposure to information related to COVID-19 through various channels such as mass media and social media platforms is strongly correlated with an increasing prevalence of psychological health concerns (31). There have been worries raised over the potential influence of social media on mental health amidst the ongoing pandemic. Several studies have established a correlation between heightened use of social media platforms and an elevated susceptibility to depression. Additionally, exposure to adverse news articles and postings has been identified as a contributing factor to the risk of depression in certain individuals (32). The proliferation of misinformation on the internet, commonly referred to as the "infodemic," encompasses the dissemination of inaccurate information pertaining to COVID-19, such as unverified remedies, the propagation of anti-Asian sentiments, and the circulation of conspiracy theories. This phenomenon has been identified as a contributing factor to heightened levels of anxiety and stress among those who are already grappling with the impacts of the pandemic (33). The present study conducted a meta-analysis of 14 cross-sectional studies, which collectively examined the relationship between excessive usage of social media platforms and the prevalence of anxiety and depressive symptoms among the general population. The findings of this meta-analysis indicate a significant positive association between the amount of time individuals spend on social media platforms and the likelihood of experiencing heightened levels of anxiety and depressive symptoms (3). Nevertheless, several research have indicated that social media can serve as an adaptive mechanism for coping, leading to a decrease in stress and anxiety levels. Social media has been recognized as a potential mechanism for augmenting social support among individuals who face challenges in finding sufficient offline social support networks (34, 35). The user's text does not contain any information to rewrite. The scholarly literature has examined the changes in social media behavior pre- and post-SARS-CoV-2 infection, as well as explored the influence of social media on mental health in the context of the COVID-19 pandemic (34, 36, 37).

The time frame adhering to the COVID-19 pandemic has initiated a significant shift in the complex interplay between mental health and the patterns of social media. The emergence of the COVID-19 pandemic led to a significant spike of internet connectivity, resulting in a huge rise in the usage of social media platforms. A comprehensive comprehension of this intricate concept is crucial in the formulation of precise interventions that effectively utilize the advantageous aspects of social media, while concurrently minimizing the possible adverse impacts on mental well-being.

The present work provides a comparative analysis of contemporary research studies, focusing on their methodological foundations, dataset features, accuracy measures, and inherent limits. Through a comparative analysis of these fundamental elements, it is possible to ascertain the merits and limitations of each methodology, so cultivating a holistic comprehension of the existing scholarly terrain. Table 1 presents a comprehensive summary of these aspects, facilitating the comprehension of readers regarding the intricacies and consequences of each study.

3 Proposed method

The proposed HybridMicroNet architecture proposed to recognize facial microexpressions using an improved deep-learning network is shown in Figure 1. It is designed to effectively capture and analyze subtle micro-expressions, along with a hybrid novel feature extraction approach. The model consists of multiple layers that extract and process facial features at a granular level, enabling accurate emotion detection. The proposed framework architecture is divided into four phases. The first phase is related to extracting video frames (10 frames per second) from an input video. The second phase involves converting the retrieved images from the video to grayscale, applying the Haar-cascade classifier to identify faces, and then resizing the image to 224×224. The third phase involves extracting features using the VGG-16 model with pre-trained weights. To predict the emotion at the final phase, a hybrid model that combines VGG-16 and ResNet is implemented.

3.1 Data pre-processing

The first step in pre-processing the microexpression video dataset is to divide the video into frames and conversion of these frames into grayscale. The starting and ending frame is taken equally from the input video for data normalization. Ten frames per second are collected from the video and converted into grayscale images to detect the face more precisely and clearly.

3.2 Face detection

The primary goal of the face detection phase is to identify the faces present in the grayscale image. A machine learning technique called the Haar-cascades approach entails developing a classifier from an extensive number of images that are both positive and negative. Positive images are related to detected human faces, and negative images without any face images. Haar features are patterns of white and dark pixels in an image that are used for further processing. The unique values of each attribute, which can identify the faces of different persons in different contexts, are calculated by deducting the sum of all the pixels in the white rectangle from the total number of

TABLE 1 Comparative analysis of contemporary research studies.

Ref.	Mental disorder	Methodology	Dataset	Accuracy	Limitation
(22)	Depression	Clinical interviews, Hamilton depression rating scale, Z-Face technology, SDAE	Self	78.67%	Small sample size, no healthy control participation
(23)	Depression	BDI score, MRLBP-TOP, Support Vector Regression, GMM	AVEC-2013, AVEC-2014	MAE-7.55 RSME-9.20	Lack of consideration of gender, age and ethnicity for assessment
(24)	Depression	3D-RNN, convolutional 3D network, BDI-II Score	AVEC-2013, AVEC-2014	MAE-7.37 RSME-9.28	Facial analysis done only on loose-face and tight-face, No emotion classification
(25)	Depression	SVM, CNN, RF	AVEC-2016	F1 score-0.746	Small sample size
(26)	Depression	MAFF, STA, SVR, BDI-II score	AVEC-2013, AVEC-2014	MAE-6.14 RSME-8.16	Model accuracy can be affected by noisy & low-quality data Results may vary in real-world clinical settings
(16)	Anxiety and Depression	LBP, VGG, HOG, BDI-II, SATI, SVM	AVEC-2014	MAI-12.48, 9.48 RSME-16.73, 12.42	Small sample size, Accurcy depends upon the video quality, results may differ on different population
(27)	Emotion Recognition	VGG-16, LSTM, Recurrent CNN	CASME-II, SAMM	F1-score – 0.50 WAR-0.5244 UAR-0.4396	It contains a large number of parameters may increase the risk of overfitting
(28)	ASD	CNN, HOG, SVM, SVR, MANOVA	Self	F1-score (1, 27) for ASD & TD	Small sample size, Limited data collection, lack of longitudinal data, lack of consideration of cultural factors
(29)	older adult Depression	VGG-16,	Self, CASME, SMIC, SFEW, VAM	F1-score Mean Recall	Limited range of micro-expressions, results can be biased due to age-related changes in facial appearance
(30)	MDD	VGG-19, SVM, LR,	12-subjects videos from youtube	AUC -0.72	Small sample size, cross-cultural differences can affect the results accuracy

pixels in the black rectangle. The captured images are enhanced by a non-linear image processing technique to improve the contrast of micro-expressions. The last step of face detection is to resize the image into 224 × 224 to be used as an input to the feature extraction phase.

3.3 Feature extraction

A deep convolutional neural network, the VGG-16 model, is used to extract the shape, texture, edge, color, semantic, and conceptual features from the images for micro-expression detection. VGG-16 model has been pre-trained on a large image dataset, which allows it to learn the different features. This model was initially used to predict the probability of the image pixels into specific feature category classes such as texture, edge, and shape.

3.4 Emotion recognition

A new architecture of ResNet model is implemented to recognize emotions, which receives the features from the VGG-16 model and is further used for training and testing of data. The proposed HybridMicroNet model takes two optional parameters: the shape of the input data and the number of output classes for classification. Fundamental characteristics are extracted from the input image by the first convolutional layer. Spatial dimensions are increased by applying zero padding to ensure the convolutional layer's output matches the dimensions of the input image data. The padded input is fed into a 2D-convolutional layer that has batch normalization and ReLU activation. The input image with size 224 × 224 is subjected to the convolutional layer with 16 filters and a 7×7 kernel size and 2 × 2 stride size with padding 2. The result of the ReLU activation layer is fed to a max pooling layer that uses a 3×3 kernel size as well as a stride of 2.

A function has been developed that repeats a two-layer module built up of successive convolutional layers, batch normalization layers, ReLU activation layers, and another convolutional layer. This function defines the building blocks for the CNN model. It requires three parameters: filters (a list of two numbers that indicates how many filters there are for each of the two convolutional layers), f (the kernel size for convolutional layers), and X (the input tensor). A number of filters can be specified in the two convolutional layers. Additionally, the function projects the shortcut connection X_shortcut in a manner that ensures the dimensions match correctly. In case the number of filters in the shortcut (X_shortcut) differs from the number of filters in the output of the convolutional layers, a 1×1 convolutional layer is applied to X_shortcut to bring the number of filters in line. After that, the outcome is subjected to batch normalization. A residual connection is formed by adding the shortcut connection and the

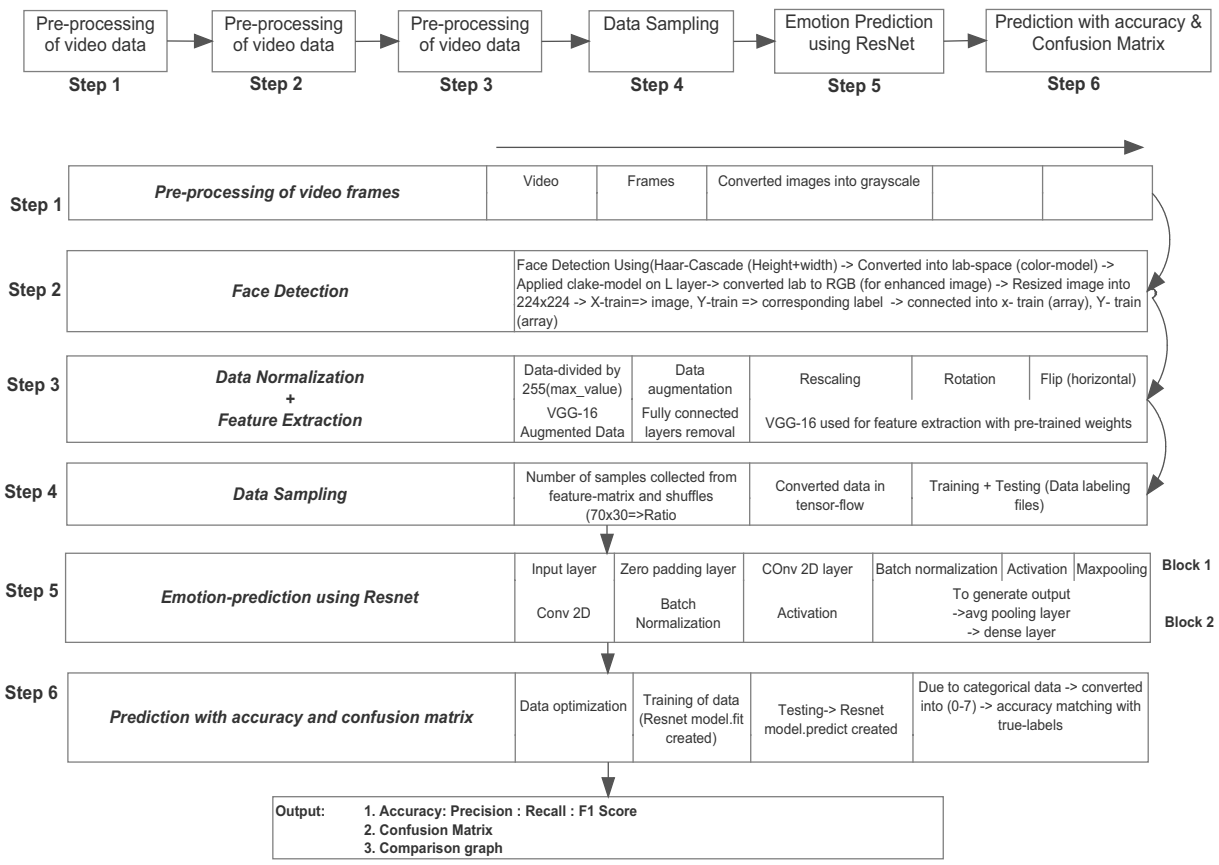

FIGURE 1
Proposed HybridMicroNet framework architecture.

TABLE 2 Network configuration of HybridMicroNet.

Layer type	Output shape	# of parameters
Conv2D (7×7, 16 filters)	(4, 4, 16)	5024
BatchNormalization	(4, 4, 16)	64
MaxPooling2D	(1, 1, 16)	0
Conv2D (3×3, 16 filters)	(1, 1, 16)	2320
BatchNormalization	(1, 1, 16)	64
Conv2D (3×3, 16 filters)	(1, 1, 16)	2320
BatchNormalization	(1, 1, 16)	64
Add	(1, 1, 16)	0
Conv2D (3×3, 32 filters)	(1, 1, 32)	4640
BatchNormalization	(1, 1, 32)	128
Conv2D (3×3, 32 filters)	(1, 1, 32)	9248
BatchNormalization	(1, 1, 32)	128
Add	(1, 1, 32)	0
GlobalAveragePooling2D	(32,)	0
Dense (Output Layer)	(2,)	66
Total	–	23702

convolutional layer output element-wise. The obtained tensor is then returned after the sum is subjected to a ReLU activation.

The function RLayers is called twice, adding to the output of the preceding layer a predetermined pattern of convolutional layers with batch normalization. The resulting feature maps are subjected to global average pooling. The class probabilities are generated using a fully connected (FC) dense layer using a softmax activation function. Table 2 shows the network configuration of the HybridMicroNet model.

4 Experiment and results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

4.1 Datasets

A benchmark dataset CASME-II obtains 249 data samples of 26 Asian volunteers with 22.03 average age producing spontaneous micro-expressions. Every picture is 640 × 480 pixels in resolution, with the face area measuring about 280 × 340 pixels. Depending on the circumstances that most appropriated the emotional state, the dataset was acquired at different intervals of time. CASME-II is a fully labeled dataset with high resolution, which offers assurance in the algorithm's evaluation and testing purposes. The participants were depicted in five

types of micro-expressions such as Disgust, happiness, Surprise, Repression and Others (38, 39).

SAMM datasets obtains 159 samples at 200 frame per second from 32 subjects with 2040 × 1,088 resolution. The facial region area is about 400 × 400 resolution. There are seven classes of emotion with other expression such as sadness, happiness, fear, disgust, surprise, anger, contempt, and others (40).

4.2 Implementation

The input image with dimensions of 224 × 224 was given padding with three additional pixels on all sides, and the value 1 was assigned to each of these padded pixels. The input image with dimensions of 224 × 224 was given padding with three additional pixels on all sides, and the value 1 was assigned to each of these padded pixels. The images underwent various forms of data enhancement, such as rescaling, rotation and having their orientations flipped horizontally. Additionally, VGG-16 model last three fully connected layers were removed to obtain features extracted from images. A feedforward weight activation approach was used to generate residual attention units throughout the training process. Stochastic Gradient Descent (SGD) technique was used for training with 64 batch size. Training was carried out with the use of a technique called stochastic gradient descent (SGD), and the batch size was set to 64. A rate of 0.001 has been applied for the application of weight deterioration, while a value of 0.5 was applied for momentum. Throughout the training process, these hyperparameters determine how the model's weights are modified. Categorical Crossentropy is a loss function that is frequently used for multiclass classification. This function refers to the idea of negative log-likelihood in order to quantify the dissimilarity that exists among predicted probabilities and the actual labels. Training of data using a batch size of 32 and ten epochs, along with a validation function to assess the performance of the model.

4.3 Evaluation metrics

To evaluate the performance of the proposed model, testing on the rest part of data (test_data) has been performed for emotion prediction. It is possible that the model is supplying probability scores or continuous values, a round function is applied to round off the nearest whole number to resolve this problem. Function assigns the test labels to all the images in which the model's most confident prediction is for the class that has the best accuracy. This function applies the function to all the images in the dataset. CASME-II and SAMM datasets are used to predict emotions in five and seven classes through confusion metrics (shown in Figures 2, 3) and accuracy, precision, recall and F1-score (Table 3).

4.4 Discussion

The comparison of proposed methodology with existing state-of-the-art approaches in the domain of machine learning-based micro-expression recognition highlights the notable progress that has been made. The advantages of proposed technique is validated through a comparative examination against established approaches, demonstrating improved precision, recall, accuracy and overall performance measures.

The LBP-TOP approach (41), involves the extraction of features into an SVM classifier. Despite outperforming hand-crafted solutions, these approaches demonstrate limitations in sustaining high levels of accuracy in real-time scenarios. In another study (42) a method introduced for deriving local quantized patterns based on spatiotemporal information. The aforementioned approach demonstrates the ability to acquire dynamic patterns; nonetheless, its performance outcomes were not deemed satisfactory. In this study (43), researcher used data augmentation methods to produce synthetic images, which were subsequently employed in the training process of a CNN. In order to accurately classify optical flow properties of facial micro expressions, it was necessary to acquire and retain crucial motion characteristics. One potential limitation of this approach is the potential loss of crucial temporal information through the generation of synthetic data.

In a further study (44), a methodology employed that encompassed the extraction of spatiotemporal data from facial images, which was subsequently processed using a three-dimensional convolutional neural network (3D CNN). The MicroExpSTCNN method encompasses the extraction of information from all pixels inside an image, whereas the MicroExpFuseNet method focuses on extracting information just from the regions of the eyes and mouth. While previous research (44) has demonstrated impressive accuracy rates when utilizing the CASME II and SMIC datasets, it is important to note that real-time prediction may still be susceptible to false positives and false negatives as a result of employing 3D CNN filters for computation. Subsequently, a three-dimensional flow approach (45) has introduced which involved employing a CNN model for the purpose of recognizing micro expressions in video-based contexts. It presents similar limitations as those discussed in reference (44). The Lateral Accretive Hybrid Network (LEARNet) (46) employs a specialized domain-specific area that incorporates depth maps and

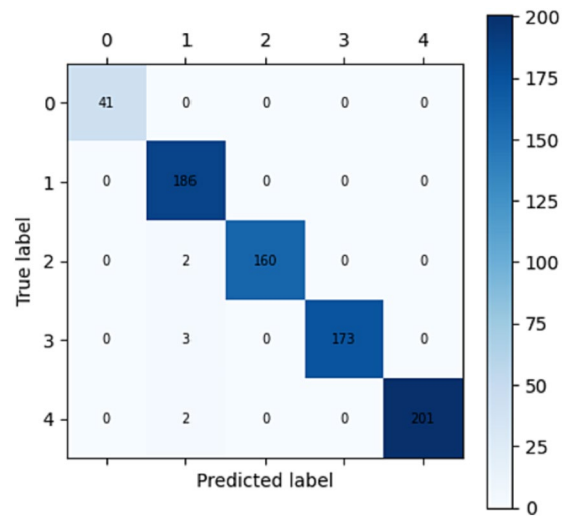

FIGURE 2
Confusion matrix for CASME-II dataset for five classes: 0-Happiness, 1-Repression, 2-Surprise, 3-Disgust, 4-others.

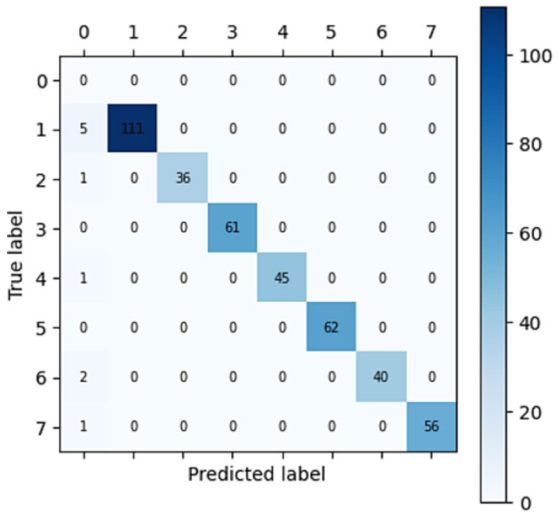

FIGURE 3
Confusion matrix for SAMM dataset with seven classes: 0-Happiness, 1-Surprise, 2-Anger, 3-Disgust, 4-Sadness, 5-Fear, 6-Contempt, and 7-Others.

TABLE 3 Comparison of accuracy measures between datasets.

Dataset	Accuracy	Precision	Recall	F1-score
CASME-II	99.08	99.12	99.08	0.99
SAMM	97.62	100	97.62	0.98

performs computations using ResNet and convolutional layers. The LEARNet image network specifically developed for the purpose of accurately identifying and analyzing micro expressions. This study presents a novel approach for capturing and preserving facial movement information in a single frame by utilizing a dynamic representation of micro-expressions.

The facial landmarks frame-wise were extracted by a 2D landmark feature map (LFM) and CLFM (47), which were subsequently fed directly into the CNN-LSTM composite architecture. This methodology places emphasis on all facial areas, resulting in a degradation of the outcomes rather than accurately identifying the primary focal points within the film. Therefore, the outcomes were not entirely precise and exhibit limited proficiency in identifying a small range of emotions. Furthermore, The Lossless Attention Residual Network (LARnet) framework (19) was proposed which exhibits a modest improvement over the 3D model presented in the (44) study. LARNet framework described as a computational model that employs feature fusion extraction techniques on distinct facial regions to effectively identify micro expressions with high precision. The HybridMicroNet framework, as depicted in Figure 4, exhibits superior performance compared to existing techniques in terms of accuracy.

4.5 Challenges

The implementation and integration of HybridMicroNet architecture provide significant prospects and intricate challenges in the discipline of accurate and effective face micro-expression recognition. This section highlights and delves into multifaceted challenges encompassing implementation, model design, dataset characteristics, and result evaluation. The issues encompass a diverse array of subjects, spanning from the intricacies of optimizing and scaling models to the ethical implications of utilizing data. Furthermore, the presence of dataset restrictions, model interpretability, and assessment measures provide substantial challenges that require meticulous consideration and innovative resolutions. The enhancement of facial micro-expression recognition models can be significantly advanced through a comprehensive analysis and resolution of the challenges pertaining to their feasibility, accuracy, and practicality. The proposed HybridMicroNet architecture presents significant challenges and considerations pertaining to its implementation, model design, dataset selection, and the resulting outcomes.

1 Implementation Challenges:

1.1 Data Pre- processing: The attainment of real-time performance, particularly in the realm of video analysis and emotion identification, is a notable challenge. The computing requirements associated with the processing of many frames per second, while simultaneously ensuring correctness, may impose a burden on available resources and impede the timely implementation of the system (20).

1.2 Scalability and Optimization: The attainment of scalability and optimization in the proposed method, with regards to properly managing larger datasets or accommodating varied input resolutions, may provide complications in practice. Achieving scalability necessitates the utmost significance of effectively managing memory, processing resources, and model inference time (48).

2 Dataset Considerations:

The limited size of accessible datasets for micro-expression identification could restrict the model's capacity to effectively learn a wide range of intricate and subtle expressions. In spite of concerted endeavors to promote diversity within datasets, it is possible for them to possess intrinsic biases, which might subsequently impact the model's capacity to effectively apply to real-world situations. The problem lies in effectively addressing biases associated with race, age, gender, and emotional expressions present in the dataset (18).

3 Model Design:

The HybridMicroNet is a neural network model that combines architectural components from VGG-16 and ResNet. Achieving optimal performance with this model requires meticulous modification of hyperparameters such as learning rate, layer structure, batch size, frame size, and regularization approaches (49).

4 Cross-Dataset Evaluation:

The assessment of the model's performance on different datasets with distinctive characteristics presents difficulties in evaluating its adaptability and robustness in various contexts. The validation of the

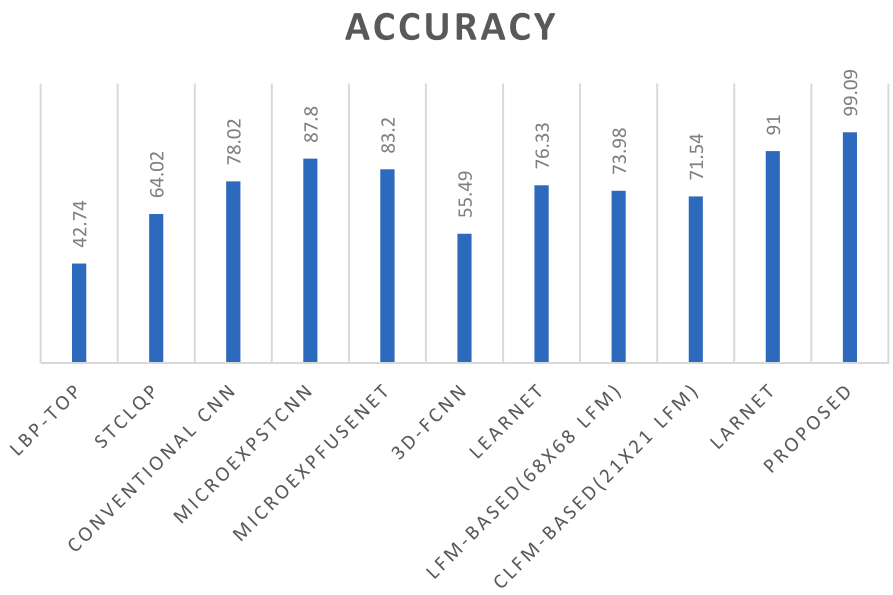

FIGURE 4
Comparison between state-of-the-art techniques with proposed method.

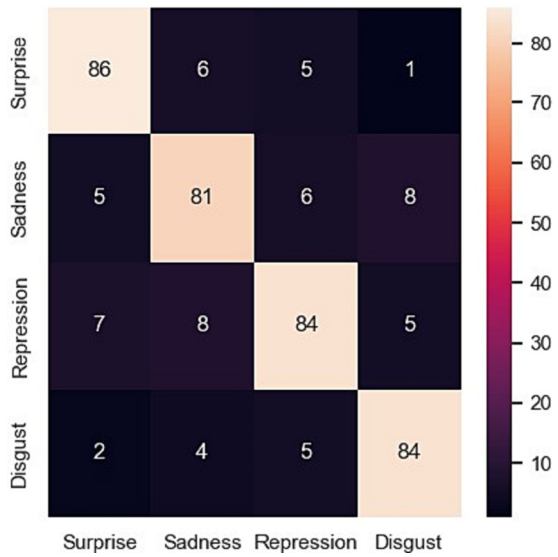

FIGURE 5
Confusion matrix for use case analysis.

model across different datasets is essential for gaining insights into its capacity to generalize beyond the training data (16).

5 Case study

Depression is a challenging mental health condition that affects millions of people all over the world. To be able to provide adequate help to individuals who are in need, early detection and intervention at the proper time are both essential. This case study investigates the use of a proposed model for emotion recognition. The experiment achieved 99.08% accuracy for CASME-II dataset and 97.62 accuracy for SAMM dataset to predict the emotions, which validated with the true label given in both datasets. Experimentation on real-time development of the trained model on the data of depressive patients was obtained from the YouTube site. This dataset comprises videos of people who had been clinically diagnosed with depression as well as some with stress, major depressive disorder, and post-traumatic stress disorder. The data was properly checked to ensure that it included a sample that was representative of all relevant demographics, including gender, age, and ethnicity. Testing on the depression patient dataset provides the results that depressed individuals express more negative emotions such as disgust, sadness, repression, and surprise, as shown in Figure 5.

The challenge of detecting and addressing depression, a prevalent mental health condition impacting millions globally, necessitates timely intervention and accurate detection methods. This case study delves into the exploration of an innovative model for emotion recognition, particularly focusing on its application in identifying emotions among individuals diagnosed with depression. However, during the evaluation of the model using real-time data obtained from individuals who have been diagnosed with mental illness and sourced from YouTube videos, many shortcomings were identified and are outlined as follows:

5.1 Dataset representation

Despite attempts to achieve diversity in terms of gender, age, and ethnicity, it is acknowledged that the dataset may not comprehensively encompass the wide range of variances observed among individuals with depression. The extent to which the dataset accurately represents the whole range of depressed symptoms and severity levels may be constrained, which could have implications for the model's capacity to be applied to a broader population (18).

5.2 External validity

The reliance on a specific dataset sourced from YouTube raises concerns regarding the generalizability of the conclusions, since it may not sufficiently capture the broader population of individuals affected by depression. The model's performance may demonstrate fluctuation when applied to datasets with various characteristics or when tested in real-world scenarios, hence impacting its external validity and generalizability (50).

5.3 Challenges in real-time applications

Although the model demonstrated a high level of accuracy in offline trials, its implementation in real-time scenarios may encounter obstacles pertaining to processing resources, latency, and the ability to adapt to dynamic, real-world conditions (18, 51).

5.4 Labeling accuracy

The study presents a significant level of precision in forecasting emotions; however, it is crucial to recognize the potential challenges linked to accurately classifying emotions, particularly in the context of mental health disorders like depression. The veracity of the labels that depict the actuality within the dataset could potentially be affected by the subjective nature of interpreting emotional expression and any biases in the labeling process (52).

5.5 Ethical considerations

The utilization of data derived from YouTube, specifically videos featuring persons who have received clinical diagnoses for mental health illnesses, gives rise to ethical considerations pertaining to issues of consent, privacy, and the safeguarding of data confidentiality (53).

6 Conclusion and future scope

The investigation of mental health detection using micro-expressions and machine learning has shown tremendous potential in the field of mental health evaluation and support. Micro-expressions represent brief and involuntary facial expressions that people make without even realizing it, and they can reveal important information about how people are feeling. It is possible to teach machine learning algorithms to recognize micro-expressions with a high degree of accuracy, even when these expressions are ephemeral or subtle. This case study has proved the potential of using micro-expressions as a helpful source of information for spotting indicators of many mental health issues, including depression and anxiety.

Traditional techniques of assessing mental health, such as self-report questionnaires and clinical interviews, have their fair share of flaws, some of which may be circumvented with the help of this methodology. Self-report questionnaires have a risk of producing erroneous results because respondents may be unaware of their mental health issues or may be reluctant to disclose them. Clinical interviews may prove expensive as well as time-consuming, and there is no guarantee that everyone who requires them will have access to them.

The findings obtained by implementing the HybridMicroNet architecture show that it has the potential to recognize face micro-expressions, which is an important area of research. The model demonstrates great proficiency in identifying minor emotional cues, as seen by its accuracy rates of 99.08% on the CASME-II dataset and 97.62% on the SAMM dataset, respectively. Its multi-phase technique, which involves face detection based on the Haar cascade and feature extraction using models such as VGG-16 and ResNet, is able to effectively capture subtle facial traits that are essential for micro-expression identification. The architecture is resilient in the sense that it can recognize a wide variety of feelings, which reflects its adaptability to a number of different emotional states. Understanding the functionality of the model is made easier by in-depth insights into the configuration of the model, which provide light on the architectural components of the model. Evaluation metrics, such as confusion matrices and accuracy measurements across a variety of emotions, provide a holistic perspective on the performance of the model. However, the study draws attention to obstacles such as limitations of datasets, and the model's interpretability, highlighting the need for future development to improve accuracy and applicability in real-world circumstances.

The findings of the proposed architecture, that exhibit remarkable accuracy rates in facial micro-expressions identification, have potential implications for mental health, particularly in the post COVID-19 era. This technical development has a tremendous amount of potential applications in the field of mental health, and it offers an opportunity gateway for early identification and intervention. Tools such as the HybridMicroNet architecture could prove to be essential tools as nations struggle to recover from the effects of the COVID-19 pandemic, which has led to an increase in the prevalence of mental health problems.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

DS: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. JS: Conceptualization, Methodology, Software, Supervision, Writing – original draft, Writing – review & editing. BS: Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing. FA: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. AA: Conceptualization, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. MA: Conceptualization, Data curation, Methodology, Software, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Stress, resilience, and moral distress among health care providers in oncology during the COVID-19 pandemic

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Background: The coronavirus pandemic has potential implications for stress levels and resilience among oncology healthcare professionals (HCPs). This study aims to assess perceived stress, resilience, and moral distress levels among oncology HCPs in Jordan during the pandemic and identify associated risk factors.

Methods: An online cross-sectional survey was conducted among oncology HCPs in Jordan using three validated tools: Perceived Stress Scale (PSS), Connor-Davidson Resilience Scale (CD-RSIC), and Moral Distress Thermometer (MDT). Seven items were used to assess sources of stress.

Results: A total of 965 participants enrolled with a 74% response rate. The participants' ages ranged from 20 to 74 (mean = 32.74, SD = 5.197), with 79.1% males, 45.1% were physicians, 32.6% were public hospital workers, 57.1% were married, and 56.6% had children below 18 years. Findings indicated moderate perceived stress (Mean = 15.87, SD = 5.861), low resilience (Mean = 29.18, SD = 5.197), and high moral distress (Mean = 4.72, SD = 2.564). Females, unmarried individuals, and younger age groups exhibited higher PSS ($p = 0.009$, $p < 0.001$, and $P<0.001$) and lower resilience ($p = 0.024$, $p = 0.034$, and $p = 0.001$). Not having children below 18 years correlated with higher perceived stress ($P < 0.001$). In linear regression analysis, age and gender emerged as significant predictors of both perceived stress and resilience. Female participants reported stress related to the risk of contracting COVID-19 ($p = 0.001$), transmitting it to others ($p = 0.017$), social isolation ($P < 0.001$), and having children at home due to school closures ($p = 0.000$). A cohort of 239 participants repeated the survey within a two-month interval, revealed a statistically significant decrease in the CD-RISC scores ($p < 0.001$).

Conclusion: Oncology HCPs in Jordan experienced moderate stress, high moral distress, and poor resilience during the COVID-19 pandemic. These factors may negatively affect the quality of oncology care. Urgent measures are necessary to support HCPs in coping with unforeseen circumstances in the future.

KEYWORDS

coronavirus pandemic, stress levels, resilience, oncology healthcare professionals, Perceived Stress Scale (PSS), Connor-Davidson Resilience Scale (CD-RSIC), Moral Distress Thermometer (MDT), Jordan

1. Introduction

1.1. Overview of the COVID-19 situation in Jordan

Jordan, which was recently downgraded as a lower-middle-income country at the close of 2022 (1), boasted a population of 11,285,869 (2). The demographic landscape in Jordan skews towards a predominantly youthful population. In 2021, approximately 71% of the inhabitants fell within the age bracket of 15–65; while a 3.7% were aged 65 and older (3). Jordan's experience with COVID-19 has seen several waves and government responses. The first case emerged in March 2020, with initial success in containment. However, by October 2020, the first wave hit, peaking in November with over 26,000 cases and 468 deaths (4). The virus was initially contained in refugee camps, with a high recovery rate among affected refugees (5). Recovery began in May 2021, with low daily cases until November when a third wave occurred, peaking in December 2021 with 34,735 cases and 226 deaths. Despite these waves (4), intensive care unit capacity remained manageable (6).

In January 2022, Jordan faced a fourth wave, with a significant portion linked to the Omicron variant. By February 2022, Jordan reported 1,490,473 cases and 13,532 deaths (4), but ICU and ventilator occupancy remained below alarming levels (6).

Jordan's response to COVID-19 has been characterized by proactive measures, vaccination campaigns, and policies aimed at restoring normalcy while managing the evolving challenges of the pandemic. Early on, safety measures were implemented, including quarantine, lockdowns, and curfews (7, 8). A vaccination campaign began in January 2021, prioritizing high-risk groups (9). By June 2021, over 2 million adults received the first dose, with additional funding from international partners to accelerate vaccination efforts, including refugees (10).

1.2. Understanding COVID-19 impact on healthcare providers

Healthcare providers (HCPs) worldwide have faced numerous challenges and stressors in response to the COVID-19 pandemic since its initial outbreak in China in December 2019 (11, 12). These challenges and stressors are often related to patient care, including limited healthcare resources, difficulties in providing the usual level of care, and patients being isolated without family support. Additionally, HCPs may experience work-related stressors such as long working hours, frequent policy and guideline changes related to COVID-19, uncertainty regarding protocols, and fear of infection, especially when there is insufficient protective equipment. Furthermore, HCPs may encounter additional challenges due to social isolation, lockdowns, and the need to care for their own children at home due to school closures (11–13).

The specific challenges faced by HCPs can vary depending on their involvement in the care of COVID-19 patients. For instance, frontline and intensive care unit HCPs may experience higher levels of stress and challenges compared to others (14, 15). Moreover, HCPs involved in cancer care may face additional and significant challenges that are compounded by pandemic-related issues such as medication and HCP shortages. Healthcare systems need to carefully balance the benefits of providing cancer treatment against the risk of COVID-19 transmission in the hospital environment, taking into account the vulnerability of cancer patients with compromised immunity (16).

Various studies have examined stress levels and mental well-being among HCPs in stable environments using different assessment tools. For example, Abraham et al. (17) assessed stressors, morale, and coping mechanisms among staff working in emergency units. Magnavita et al. (18) examined mental and physical well-being in cancer units using the needs questionnaire and positivity scale. While several studies have explored stressors in rapidly evolving environments like COVID-19, William and Lancee (19) found that HCPs reported long-term stress during the SARS outbreak but their mental status remained unaffected. These studies have contributed to the development of strategies to enhance resilience and reduce stress by promoting safety measures, comfort, and social connections (20).

Marjanovic et al. (20) conducted an online survey among 333 nurses to assess the association of the working environment with psychosocial variables. The study focused on predictors of coping attitudes, emotional exhaustion, and anger using validated tools such as the State–Trait Anger Expression Inventory and the Maslach Burnout Inventory. Results showed that lower emotional exhaustion levels were predicted by higher institutional support, less contact with SARS patients, and shorter quarantine times. Maunder et al. (21) surveyed staff members from 13 hospitals in Toronto, Canada, to assess the impact of SARS on their psychological and occupational well-being 13–26 months after the outbreak. The study revealed higher levels of stress and burnout among staff working in SARS treatment hospitals, reduced working hours, and stress-related behavioral consequences.

In their study, Motahedi et al. (22) underscored the significance of addressing the mental health challenges encountered by HCPs during the COVID-19 pandemic. They conducted an investigation involving 140 HCPs in an urban region of Iran. The findings revealed the presence of moderate anxiety levels alongside concurrent moderate to severe depression among the HCPs. Notably, gender, a history of COVID-19-related quarantine, and previous exposure to COVID-19 were identified as factors associated with elevated levels of both anxiety and depression. Given that working in institutions treating COVID-19 patients may expose HCPs to stress and mental health issues, it is important to identify potential stressors and challenges specific to oncology HCPs in Jordan. Tracking changes over time can provide preliminary baseline data to inform future policies and studies, particularly considering the scarcity of research in this

area in Jordan. The objectives of this survey are: (1) to describe the impact of COVID-19 on oncology HCPs in Jordan by assessing self-reported perceived stress levels, resilience, and moral distress, (2) to compare these findings within different HCP groups (e.g., nurses vs. doctors, ambulatory vs. in-patient care), and (3) to conduct longitudinal assessments of these mental wellness dimensions over time as the COVID-19 environment evolves.

2. Materials and methods

2.1. Study design and participants

The study employed a cross-sectional survey with a longitudinal assessment to quantify perceived stress, its sources, resilience, and moral distress among oncology healthcare professionals (HCPs) in Jordan. Data collection was conducted using the Survey Monkey platform from November 9, 2020, to April 28, 2021. The study included frontline HCPs (e.g., doctors, nurses, pharmacists, psychosocial workers) who worked full-time or part-time during the pandemic in COVID-19-designated hospitals in Jordan, encompassing in-patient, ambulatory, and administrative care settings. HCPs who did not work in COVID-19-designated hospitals, did not work at least part-time during the pandemic, or were on vacation were excluded from the study.

2.2. Data collection

Data was collected through a structured survey instruments that incorporated both validated psychological scales and demographic information. The data collection process aimed to capture the experiences and mental well-being of oncology HCPs in Jordan during the COVID-19 pandemic.

2.3. Data collection instruments

2.3.1. Perceived Stress Scale (PSS-10)

The PSS is a validated self-reported tool used to measure stress levels in individuals who perceive their lives to be unpredictable, uncontrollable, and burdensome over the past month (23). Originally introduced in 1983 by Cohen and colleagues (23), where the PSS initially comprised 14 items. Participants are required to rate the frequency of their experiences of emotions and thoughts associated with life events and situations over the preceding month using a five-point scale, ranging from (0) "Never" to (4) "Very Often." The cumulative score derived from the PSS serves as a comprehensive measure of perceived stress. A short version of the PSS (PSS-10) was developed by Cohen and Williamson (24) in 1988. This adaptation was created by excluding four items with the lowest factor loadings from the original scale. The psychometric characteristics of the PSS-10 were initially assessed in a large national sample in the United States. The PSS-10 demonstrated satisfactory internal consistency reliability ($\alpha = 0.78$). Furthermore, moderate concurrent criterion validity, as indicated by significant positive correlations with the level of stress experienced during an average week ($r = 0.39$, $p < 0.001$) and the frequency of stressful life events in the past year ($r = 0.32$, $p < 0.001$). Additionally, it exhibited adequate convergent validity, as evidenced by its associations with measures of both physical and mental health. The developers endorsed the use of the PSS-10 in future research due to its comparable psychometric properties with the original version. Furthermore, subsequent studies consistently reaffirmed these findings (25–27).

The scale consists of 4 positively worded items (4, 5, 7, and 8) and 6 negatively worded items (1, 2, 3, 6, 9, and 10), which are rated on a 5-point Likert scale (0 = never, 1 = almost never, 2 = sometimes, 3 = fairly often, or 4 = very often). The total score ranges from 0 to 40, with scores of 0–13, 14–26, and 27–40 indicating low, moderate, and high levels of stress, respectively (28, 29).

Seven Source of Stress items were added, rated on a 5-point Likert scale (0–4; 0 = not at all stressful, 4 = majorly stressful), to capture responses related to the PSS. These items were designed to assess the significance of each source of stress, including work environment, patient care, personal safety, home life, social isolation, financial toxicity, and having children at home due to school closures.

In our study, we employed both the validated English version (30) and the Arabic versions (31, 32) of the questionnaire.

2.3.2. Connor-Davidson Resilience Scale (CD-RISC-10)

The CD-RISC-10 is a validated self-reported tool used to measure resilience in individuals with post-traumatic stress disorder (PTSD) or other types of anxiety. Derived from the CD-RISC-25 (33), a 25-item scale gauging the ability to cope with adversity, respondents rate items on a five-point scale ranging from 0 (not true at all) to 4 (true nearly all the time) reflecting their feelings and experiences over the course of the past month. The total score ranges from 0 to 40 with higher scores reflecting greater resilience. Preliminary investigations into the psychometric properties of the CD-RISC in both the general population and patient samples have substantiated its internal consistency, test–retest reliability, and convergent and divergent validity (33). In a study conducted by Campbell-Sills and Stein (34), the psychometric properties of the CD-RISC-25 were examined. Their research identified an unstable factor structure in the CD-RISC across two equivalent samples via exploratory factor analysis (EFA). Following a series of modifications, a 10-item unidimensional scale was developed, exhibiting robust internal consistency and construct validity. Multiple study's results underscore the excellent psychometric qualities of the 10-item version, affirming its reliability as a tool for assessing resilience (35–37). The new version uses a five-point scale (0–4). The total score ranges from 0 to 40, with score ranges of 0–29, 30–32, 33–36, and 37–40, indicating lower to higher levels of resilience, with the median score for the general population residing at 32 (38). In our study, we employed the original English version (34) and the validated Arabic version (39) of the questionnaire.

2.3.3. Moral Distress Thermometer (MDT)

Moral distress refers to distress experienced when individuals know the morally right thing to do but are unable to do so due to perceived obligations (40, 41). In their study, Wocial and Weaver (42) initially developed and assessed the psychometric properties of a novel tool designed for detecting moral distress, referred to as the Moral Distress Thermometer (MDT). In their cross-sectional investigation, they presented compelling evidence supporting the MDT's validity as a subjective measure of moral distress among HCPs when compared to the more comprehensive Moral Distress Scale (MDS) 2009. The validation process of the MDT involved its comparison with the more

extensive Moral Distress Scale (MDS) 2009, a tool specifically designed for assessing moral issues (43). The MDT utilizes an 11-point scale, spanning from 0 to 10, along with associated verbal descriptors. Respondents are required to rate the level of moral distress they have experienced in relation to their work over the past 2 weeks. The study findings indicated a moderate correlation between the MDT and the MDS 2009, thereby confirming convergent validity. Concurrent validity was established by comparing MDT scores among different groups of nurses based on their experiences with leaving positions due to moral distress, and these results were consistent with the findings obtained using the MDS 2009. Given the dynamic and subjective nature of moral distress, the authors determined that reliability testing for the MDT was impractical. In our study, Participants are asked to circle the number that best describes the extent to which they experienced work-related moral distress over the past 2 weeks. A score of 4 and above indicates high moral distress. Both the validated English (42) and Arabic (44) versions were used.

In response to the rapidly evolving pandemic circumstances, we made the decision to shorten the recall period to 7 days (45). This adjustment aimed to capture immediate and contextually relevant stressors and experiences encountered by HCPs in their demanding roles within the healthcare system. Given that the importantly, we maintained this consistent 7-day recall period for HCPs in both the initial and subsequent survey waves. This deliberate approach enabled us to longitudinally evaluate stress level, resilience and moral distress while taking into account the dynamic nature of the pandemic's impact on HCPs.

2.3.4. Socio-demographic data

Socio-demographic data included gender (male or female), occupation (e.g., doctor, nurse, other HCP), age group (≤ 33, > 33), marital status, having children below the age of 18, workplace (in-patient, out-patient, administration), and health sector (MOH, RMS, Private Sector, University hospitals, KHCC).

2.4. Measurement translation

Systematic and culturally sensitive translations of the three validated measurements into Arabic for use in the context of Jordan, This comprehensive process strictly adhered to the EORTC (European Organisation for Research and Treatment of Cancer) translation procedures (46). This involved independent forward translations by two bilingual speakers with End-of-Life Care (EoLC) knowledge, professional back translation, and harmonization of all versions.

Then, we systematically compared our reconciled Arabic version with the Arabic-validated questionnaires for PSS, CD-RISC and MDT. This meticulous comparison revealed that there were no disparities between our translated versions and the established and validated Arabic tools designed for these measurements. Consequently, we decided to utilize the three previously validated Arabic versions of the questionnaires (PSS-10, CD-RISC-10, and MDT).

2.5. Data collection procedure

The survey was primarily conducted through an online survey platform to ensure participant anonymity and safety during the pandemic. Participants were provided with secure links to the surveys, which were accessible on various devices. The survey was available in Arabic and English language to accommodate the diverse backgrounds of the participants. The eligible participants were identified and contacted by their managers, who informed them about the voluntary nature of participation and clarified that their decision would not affect their performance evaluation. Subsequently, the participants received an invitation and a survey information letter via their official emails. Interested participants contacted the research team, and those who wished to participate or obtain more information were provided with a survey link via their official emails.

A follow-up assessment was performed on a subsample of participants who agreed to repeat the measurement within 2 months of the initial survey to evaluate changes in their responses to the three validated tools over time.

2.6. Ethical considerations

Data collection was carried out in a structured and standardized manner. All participants provided informed consent before participating in the study. And were explicitly informed that their consent was implied by reading the survey information letter and completing the survey. They were also assured that they could withdraw from the study at any time without providing a reason until they submitted their completed questionnaires, after which data withdrawal would not be possible.

Ethical approval for the study protocol, including data collection procedures, was obtained from the Institutional Review Board at the King Hussein Cancer Centre (KHCC) under the reference number EC/Ref No: 20 KHCC 123.

2.7. Statistical analysis

2.7.1. Sample size estimation

In this study, we employed the Krejcie and Morgan table (47), a well-established and widely accepted method for estimating survey sample sizes. This approach prescribes a minimum sample size of 384 respondents to ensure adequate representation and randomness when dealing with a population size of 10,000.

2.7.2. Statistics

Data were collected using Survey Monkey and exported to SPSS software (V.26) for analysis. Missing data of no more than 10% were accepted by the research team using the Pairwise deletion approach. The responses were analyzed and summarized, and correlations were run with the answered items, resulting in different sample sizes per item.

The significance level was set at $p < 0.05$. The original scores of the three validated tools were presented as mean with standard deviation. The ranked data derived from the counts of each level for PSS, CD-RISC, and MDT were presented as numbers and percentages, likely indicating the distribution of responses across different levels. Independent *t*-tests and one-way ANOVA tests were used to find associations between different variables such as gender, age group, marital status, professional role, workplace, health sector, and having children below the age of 18. A paired *t*-test was performed in a

subsample to evaluate responsiveness to change. Variables that showed significance in the analysis were entered into linear regression model. Adjusted *p*-values were reported, indicating the significance of each variable while controlling for the influence of other variables in the model.

3. Results

A total of 1,310 healthcare professionals (HCPs) participated in the survey, with 965 completing the initial survey, resulting in a response rate of 74%. Among these respondents, 340 expressed their willingness to participate in a follow-up survey within 2 months, and 239 completed the second survey.

TABLE 1 Participants' demographic characteristics ($n = 964$).

	1st Survey		2nd Survey
	N (%)		*N* (%)
Gender			
Male	763 (79.1)		181 (75.7)
Female	201 (20.9)		58 (24.3)
Professional role			
Doctors	435 (45.1)		99 (41.9)
Nurses	335 (34.8)		89 (37.7)
Other HCPs	194 (20.1)		48 (20.3)
Sector			
MoH	314 (32.6)		74 (31)
RMS	126 (13.1)		22 (9.2)
University hospitals	124 (12.9)		34 (14.2)
Private sector	178 (18.5)		43 (18)
KHCC	222 (23)		56 (23.4)
Marital status			
Single	395 (41)		92 (38.5)
Married	550 (57.1)		142 (59.4)
Divorced	15 (1.6)		4 (1.7)
Widowed	4 (0.4)		1 (0.4)
Having children < 18			
Yes	546 (56.6)		130 (54.4)
No	418 (43.4)		99 (41.4)
Workplace			
In-patient	568 (58.9)		190 (54.5)
Out-patient	327 (33.9)		99 (41.4)
Admin	69 (7.2)		190 (54.5)
Age			
Mean (Range)	SD		
32.74 (20–74)	8.052		

MoH indicates Ministry of Health; RMS indicates Royal Medical Services; KHCC indicates King Hussein Cancer Centre; Other HCPs indicates any allied health professional.

3.1. Participant characteristics

Participant characteristics revealed that the majority of participants were male (763, 79.1%). The mean age was 32.74 years (range: 20–74). Among the participants, 435 (45.1%) were doctors, 314 (32.6%) worked in Ministry of Health Hospitals, 550 (57.1%) were married, 546 (56.6%) had children below the age of 18, and 568 (58.9%) worked in an in-patient care setting (Table 1).

3.2. Outcome measurements

Figure 1 summarizes the scores for the Perceived Stress Scale (PSS), Connor-Davidson Resilience Scale (CD-RSIC), and Moral Distress Thermometer (MDT) over 25 weeks. The mean scores were 15.87 for PSS, 29.18 for resilience, and 4.72 for MDT.

3.2.1. The Perceived Stress Scale (PSS)

The analysis using the Perceived Stress Scale (PSS) indicated that being female ($p = 0.009$), unmarried ($p = 0.001$), having no children below the age of 18 ($p = 0.000$), and being younger ($p < 0.001$) were significantly associated with higher PSS scores. However, occupation ($p = 0.254$), health sector ($p = 0.637$), and workplace ($p = 0.357$) did not have a significant impact on PSS scores. In the summary linear regression analysis involving independent variables and PPS-10 scores, it was observed that gender and age emerged as significant predictors for PPS-10, with $p = 0.002$ and $p < 0.001$, respectively (Table 2).

3.2.1.1. Source of stress

The sources of stress were categorized as follows: "Not at all stressful" or "Almost never stressful" (indicating minor stress), "Sometime stressful" (indicating moderate stress), and "Fairly often stressful" or "A major cause of stress" (indicating major stress).

3.2.1.2. Gender

Significant associations were observed between gender and sources of stress. Females reported higher levels of major stress from the imposed social isolation (59.7% vs. 44.5% for males, $p = 0.000$), the risk of contracting COVID-19 (51.6% vs. 39.2% for males, $p = 0.001$), the risk of transmitting COVID-19 to others (77.2% vs. 66.2% for males, $p = 0.017$), and having children home from school (46.2% vs. 29.7% for males, $p = 0.000$). No significant association was found between gender and stress related to providing patient care ($p = 0.088$), the daily work environment ($p = 0.733$), or personal or familial financial concerns ($p = 0.988$) (Table 3).

3.2.1.3. Occupation

Profession (doctors, nurses, and other HCPs) also showed a significant correlation with certain sources of stress. Other HCPs reported minor stress from providing patient care more frequently (53.0% vs. 39.2% for nurses and 32.1% for doctors, $p = 0.000$). Nurses demonstrated higher levels of major stress from the daily work environment compared to doctors and other HCPs (44.5% vs. 34.3% for doctors and 26.7% for other HCPs, $p = 0.001$). Other HCPs showed minor stress from the need for social isolation more frequently (55.6% vs. 42.3% for doctors and 49.8% for nurses, $p = 0.023$). Doctors reported minor stress from having

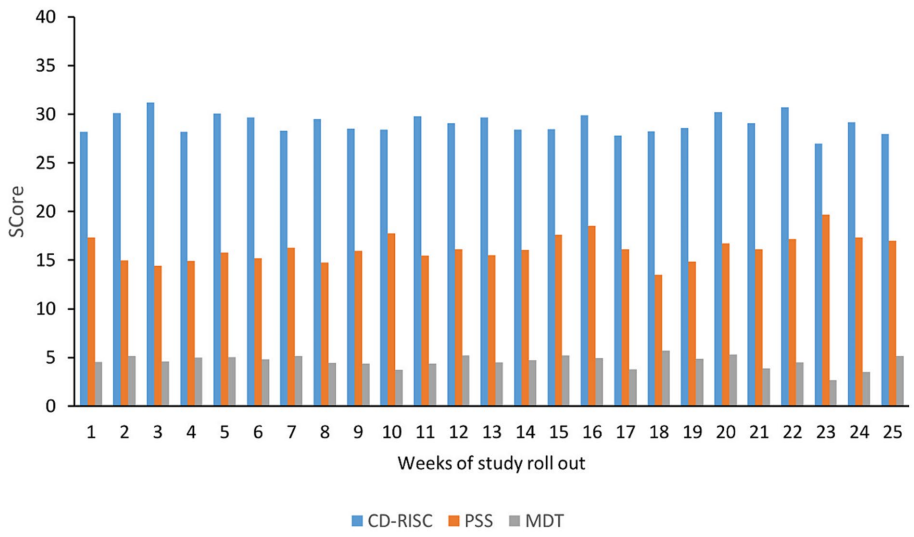

FIGURE 1
PSS, CD-RISC, and MDT scores in the initial survey: the figure illustrates the Perceived Stress Scale (PSS), Connor-Davidson Resilience Scale (CD-RISC), and Moral Distress Thermometer (MDT) scores on the vertical axis. The horizontal axis represents the week of the study rollout. PSS scores are categorized as low (0–13), moderate (14–26), and high (27–40) levels of stress. CD-RISC scores range from 0 to 29, 30 to 32, 33 to 36, and 37 to 40, with higher scores indicating greater resilience levels. MDT scores range from 0 to 10, with a score of 4 and above indicating high moral distress.

children home from school more often (61.9% vs. 46.0% for other HCPs and 39.2% for nurses, $p = 0.000$).

However, the model did not show a significant association between occupation and other sources of stress, such as the risk of contracting COVID-19 ($p = 0.301$), transmitting COVID-19 to others ($p = 0.186$), or personal or familial financial concerns ($p = 0.065$) (Table 3).

3.2.2. The Connor-Davidson Resilience Scale (CD-RISC)

Resilience significantly decreased in females ($p = 0.024$), unmarried individuals ($p = 0.034$), and those of younger age ($p = 0.001$). However, occupation ($p = 0.494$), health sector ($p = 0.114$), having children below the age of 18 ($p = 0.440$), and workplace ($p = 0.907$) did not show any significant effects on resilience. In the summary of the linear regression analysis that incorporated independent variables alongside CD-RISC-10 scores, both gender and age emerged as statistically significant predictors for CD-RISC-10, with p-values of 0.01 and $p = 0.020$, respectively (Table 2).

3.2.3. The Moral Distress Thermometer (MDT)

Throughout the entire survey period of 25 weeks, no statistically significant relationship was observed between the participants' demographic characteristics and the levels of perceived moral distress (Table 2).

3.2.4. Paired data

The statistical model revealed a significant decline only in the CD-RISC scores ($p < 0.001$) for participants in the second survey, while other outcomes remained unaffected (Figure 2).

4. Discussion

In the midst of the COVID-19 pandemic, healthcare professionals (HCPs) have faced unprecedented challenges that have significantly impacted their mental well-being. The present study aimed to assess the impact of the COVID-19 pandemic on the stress, resilience, and moral distress levels of healthcare professionals (HCPs) in Jordan over a period of 25 weeks.

The findings of the study indicate that oncology HCPs in Jordan reported moderate levels of perceived stress, low resilience, and high levels of perceived moral distress. These results are consistent with previous studies conducted during the COVID-19 pandemic (11, 12, 48, 49). The waves and peaks of the pandemic in Jordan between 2020 and 2021 likely contributed to the sustained levels of stress and distress experienced by the participants (50).

The Perceived Stress Scale (PSS) scores indicated that being female (22), unmarried (51–57), having no children below the age of 18 (51, 54), and being younger (56, 58–62) were significantly associated with higher stress levels. This aligns with previous research that has shown females and younger individuals experiencing higher stress levels during the pandemic due to factors like increased caregiving responsibilities, work demands, and concerns about personal health and safety (22, 54, 63–65). However, the lack of significant association between occupation groups, health sector, and workplace with stress scores is surprising (52, 55, 66–69). Indicating that the pandemic's stressors were pervasive across various healthcare professions and settings (66). These findings suggest that the mental well-being of all HCPs should be prioritized, irrespective of their specific roles, and targeted interventions should be implemented to provide adequate support (22).

The sources of stress reported by the participants also showed interesting patterns. Females experienced higher stress levels related to social isolation, the risk of contracting and transmitting COVID-19 (13, 22, 54, 70–73), and having children home from school. This could be attributed to gender-specific societal expectations, such as women shouldering more responsibilities related to caregiving and household tasks during the pandemic (13, 22, 70, 71, 74).

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TABLE 2 Participants' characteristics with respect to the three validated tools of the first survey.

	PSS			CD-RISC			MDT		
	N (%)	Mean ± SD	*P*	*N* (%)	Mean ± SD	*P*	*N* (%)	Mean ± SD	*P*
Gender			**0.009**			**0.024**			0.809
Male	746 (79.53)	15.61 ± 5.58		763 (79.15)	29.38 ± 5.14		726 (80.22)	4.71 ± 2.58	
Female	192 (20.47)	16.85 ± 6.78		201 (20.85)	28.45 ± 5.35		179 (19.78)	4.76 ± 2.50	
Occupation			0.254			0.494			0.196
Doctors	419 (44.67)	15.94 ± 5.72		435 (45.12)	29.16 ± 5.04		405 (44.75)	4.71 ± 2.51	
Nurses	327 (34.86)	16.13 ± 5.86		335 (34.75)	29.00 ± 5.41		315 (34.81)	4.88 ± 2.51	
Other HCPs	192 (20.47)	15.27 ± 6.15		194 (20.12%)	29.55 ± 5.18		185 (20.44)	4.45 ± 2.76	
Sector			0.637			0.114			0.247
MoH	309 (32.94)	15.81 ± 5.72		314 (32.57)	28.88 ± 5.22		302 (33.37)	4.75 ± 2.44	
RMS	119 (12.69)	15.55 ± 5.30		126 (13.07)	28.56 ± 5.33		110 (12.13)	4.55 ± 2.49	
University hospitals	121 (12.90)	15.78 ± 5.73		124 (12.86)	28.98 ± 5.36		114 (12.60)	4.18 ± 2.37	
Private	175 (18.66)	16.48 ± 5.87		178 (18.46)	29.91 ± 4.90		169 (18.67)	4.50 ± 2.80	
KHCC	214 (22.81)	15.68 ± 6.42		222 (23.03)	9.50 ± 5.18		210 (23.2)	4.70 ± 2.66	
Marital status			**<0.001**			0.034			0.586
Single	382 (40.72)	16.91 ± 5.76		395 (40.98)	28.78 ± 5.12		365 (40.33)	4.68 ± 2.57	
Married	539 (57.46)	15.06 ± 5.80		550 (57.05)	29.41 ± 5.22		524 (57.9)	4.72 ± 2.57	
Divorced	14 (1.49)	18.64 ± 6.57		15 (1.56)	29.93 ± 5.55		13 (1.44)	5.31 ± 2.43	
Widowed	3 (0.32)	14.67 ± 3.51		4 (0.41)	35.00 ± 3.16		3 (0.33)	6.33 ± 1.53	
Having children < 18			**<0.001**			0.44			0.911
Yes	528 (56.29)	15.24 ± 5.81		546 (56.64)	29.30 ± 5.21		512 (56.57)	4.73 ± 2.50	
No	410 (43.71)	16.67 ± 5.84		418 (43.36)	29.04 ± 5.18		393 (43.43)	4.71 ± 2.64	
Workplace			0.357			0.907			0.492
In-patient	550 (58.64)	15.83 ± 6.03		568 (58.92)	29.19 ± 5.11		531 (58.67)	4.77 ± 2.50	
Out-patient	322 (34.33)	15.72 ± 5.67		327 (33.92)	29.12 ± 5.35		312 (34.48)	4.69 ± 2.68	
Admin[a]	66 (7.04)	16.85 ± 5.30		69 (7.16)	29.42 ± 5.23		62 (6.85)	4.37 ± 2.50	
Age group			**<0.001**			**0.001**			0.517
≤ 33	577 (61.51)	16.72 ± 5.88		594 (61.62)	28.76 ± 5.19		555 (61.33)	4.76 ± 2.55	
> 33	361 (38.49)	14.50 ± 5.58		370 (38.38)	29.86 ± 5.15		350 (38.67)	4.65 ± 2.58	

Significant values are written in bold. $p \leq 0.05$. MoH indicates Ministry of Health; RMS indicates Royal Medical Services; KHCC indicates King Hussein Cancer Centre; Other HCPs indicates any allied health professional. [a]Admin indicates the non-medical staff.

However, stress related to patient care, the daily work environment, and financial concerns was not differentiated by gender (54).

Occupation was also linked to specific stressors such as patient care, the work environment, social isolation, and having children at home (54). While other HCPs reported more stress from providing patient care, Frontline healthcare professionals such as nurses experienced higher stress from the daily work environment, which could be linked to their direct patient care responsibilities and exposure to stressful healthcare settings (13, 57, 75–77). These findings shed light on the unique stressors faced by nurses during the pandemic. Addressing these stressors through targeted interventions, such as mental health support and flexible work arrangements, may be essential in reducing their stress levels and improving overall well-being (13). Although the results did not indicate a statistically significant difference in the Perceived Stress Scale (PSS) scores among HCPs groups regarding stress from personal or family financial concerns, it is worth mentioning that a considerable proportion of them rated it as a major source of stress. This contrasts with the findings of a recent Italian study (54). Its likely influenced by the negative economic impact on families and the national economy (78). The finding that doctors reported more stress from having children home from school is surprising and warrants further investigation. These findings underscore the importance of recognizing the distinct challenges faced by different healthcare professionals and customizing support mechanisms accordingly.

Resilience, as measured by the Connor-Davidson Resilience Scale (CD-RISC), although the participants reported low resilience levels in both surveys, which were below the average resilience score of the general population (38). The decline in resilience scores for participants in the second survey is a noteworthy finding. It suggests that prolonged exposure to the

TABLE 3 Differences between genders and occupation with respect to sources of stress.

	Gender			Occupation			
Category	Male no. (%)	Female no. (%)	*P* value	Doctor no. (%)	Nurse no. (%)	Other HCPs no. (%)	*P* value
Daily work environment							
Minor stress	178 (24.3)	38 (20.7)	0.733	99 (24.0)	60 (18.8)	57 (30.5)	**0.001***
Sometimes	297 (40.5)	72 (39.1)		172 (41.7)	117 (36.7)	80 (42.8)	
Major stress	259 (35.3)	74 (40.2)		141 (34.2)	142 (44.5)	50 (26.7)	
Total	734	184		412	319	187	
Providing patient care							
Minor stress	296 (40.3)	61 (33.2)	0.088	132 (32.0)	125 (39.2)	100 (53.5)	**<0.001***
Sometimes	280 (38.1)	71 (38.6)		187 (45.4)	112 (35.1)	52 (27.8)	
Major stress	158 (21.5)	52 (28.3)		93 (22.6)	82 (25.7)	35 (18.7)	
Total	734	184		412	319	187	
Risk of becoming infected with COVID-19							
Minor stress	250 (34.1)	41 (22.3)	**0.001***	141 (34.3)	91 (28.5)	59 (31.6)	0.301
Sometimes	196 (26.7)	48 (26.1)		108 (26.3)	96 (30.1)	40 (21.4)	
Major Stress	287 (39.2)	95 (51.6)		162 (39.4)	132 (41.4)	88 (47.1)	
Total	733	184		411	319	187	
Concerns of transmitting COVID-19 to others							
Minor Stress	79 (10.8)	15 (8.2)	**0.017***	44 (10.7)	28 (8.8)	22 (11.8)	0.186
Sometimes	167 (22.8)	27 (14.7)		96 (23.3)	62 (19.4)	36 (19.3)	
Major Stress	488 (66.5)	142 (77.2)		272 (66.0)	229 (71.8)	129 (69.0)	
Total	734	184		412	319	187	
The need for social isolation							
minor stress	174 (23.7)	25 (13.6)	**<0.001***	141 (34.3)	91 (28.5)	59 (31.6)	0.301
Sometimes	233 (31.7)	49 (26.6)		108 (26.3)	96 (30.1)	40 (21.4)	
Major stress	327 (44.6)	110 (59.8)		162 (39.4)	132 (41.4)	88 (47.1)	
Total	734	184		411	319	187	
Personal or family financial concerns							
Minor stress	121 (16.5)	29 (15.8)	0.988	76 (18.5)	50 (15.7)	24 (12.8)	0.065
Sometimes	205 (28.0)	49 (26.6)		125 (30.4)	81 (25.4)	48 (25.7)	
Major stress	407 (55.5)	106 (57.6)		210 (51.1)	188 (58.9)	115 (61.5)	
Total	733	184		411	319	187	
Having children home from school							
Minor stress	395 (53.8)	71 (38.6)	**<0.001***	255 (61.9)	125 (39.2)	86 (46.0)	**<0.001***
Sometimes	121 (16.5)	28 (15.2)		65 (15.8)	62 (19.4)	22 (11.8)	
Major stress	218 (29.7)	85 (46.2)		92 (22.3)	132 (41.4)	79 (42.2)	
Total	734	184		412	319	187	

Significant values are written in bold. *$p \leq 0.05$.

challenges of the pandemic may have eroded participants' resilience over time, potentially leaving them more vulnerable to stress and burnout (11, 54). The lack of significant changes in stress and moral distress levels may indicate that these factors are relatively stable over the 25-week period or that other external factors such as direct patient care, and the absence of effective vaccines or drugs during the study period may have contributed to a decrease in resilience among HCPs (79).

The Connor-Davidson Resilience Scale (CD-RISC) also showed a significant decline in females, unmarried individuals, and younger participants (56, 58–62). This suggests that certain demographic groups may be more vulnerable to decreased resilience during the pandemic, which could have implications for their mental health and coping abilities (80).

Contrary to some studies, no significant relationship was found between the participants' demographic characteristics and perceived

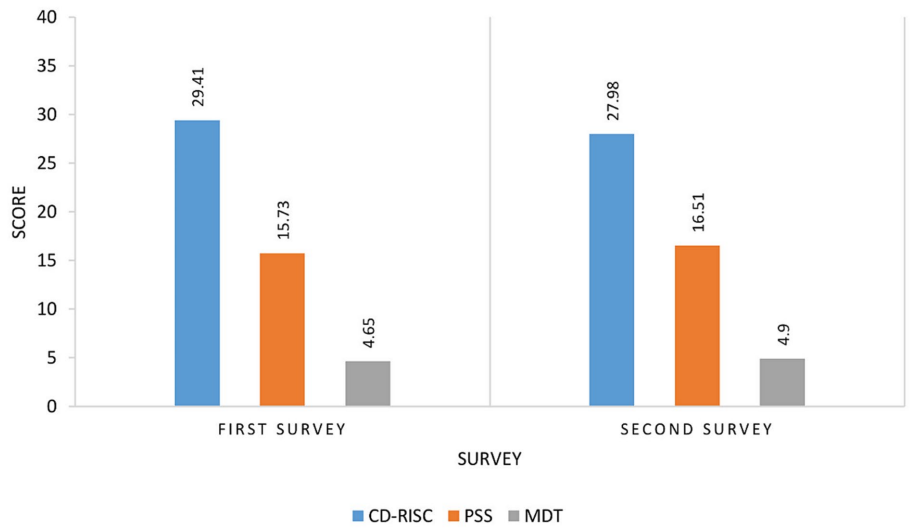

FIGURE 2
Comparison of CD-RISC, PSS, and MDT between Paired Sample (n = 239). PSS, Perceived Stress Scale; CD-RISC, Connor-Davidson Resilience Scale; MOT, The Moral Distress Thermometer. The scores of CD-RISC, PSS, and MDT are shown on the vertical line, and the horizontal line represents the paired surveys during the study roll-out. The PSS scores range from 0 to 13, 14 to 26, and 27 to 40, indicating low, moderate, and high stress levels, respectively. The CD-RISC scores range from 0 to 29, 30 to 32, 33 to 36, and 37 to 40, with a higher score indicating higher resilience. The MDT scores range from 0 to 10, with a score of 4 and above indicating high moral distress.

moral distress levels (52, 55, 67–69), indicating that moral distress may be a universal experience among healthcare professionals during the pandemic, irrespective of their individual characteristics. This highlights the collective challenges faced by healthcare professionals in navigating ethical dilemmas and moral concerns during times of crisis (67–69).

The longitudinal analysis highlighted a significant decline in resilience scores over time. This finding emphasizes the need for continuous mental health support and interventions to sustain HCPs' well-being throughout the prolonged duration of the pandemic. Implementing resilience-building programs and providing resources for stress management can aid in mitigating potential long-term effects on HCPs' mental health.

Furthermore, the lack of significant changes in stress and moral distress levels over the two-time point test may indicate that these factors are relatively stable over the 25-week period or that other external factors are compensating for the effects of the pandemic on these outcomes.

5. Strengths and limitations

The study had several strengths. First, it included a substantial sample size of 965 healthcare professionals, which enhances the representativeness of the findings. Second, a longitudinal design was employed, allowing for the examination of changes in perceived stress, resilience, and moral distress over time, providing valuable insights into the evolving psychological responses during the pandemic. Third, validated tools were used to measure perceived stress, resilience, and moral distress, increasing the reliability and validity of the study findings.

However, there were also limitations to consider. The initial survey had a cross-sectional design, limiting the ability to establish causal relationships and providing only a snapshot of participants' psychological responses. Self-report measures were utilized, which may be influenced by response biases such as social desirability bias, potentially affecting the accuracy of reported levels of stress, resilience, and moral distress. The study focused on healthcare professionals in COVID-19-designated hospitals in Jordan, potentially limiting the generalizability of the findings to other healthcare settings or regions. The absence of a control group of healthcare professionals not directly involved in COVID-19 care prevented comparisons and a deeper understanding of the unique stressors and psychological responses associated with the pandemic.

A another limitation of this study is the skewed gender representation, with the majority of participants being male. The low female participation rate may be attributed to cultural and religious factors in Jordanian society, where females may be reluctant to participate in surveys involving direct communication with unrelated males due to cultural norms and preferences for female respondents (81, 82).

Despite these limitations, the study provides valuable insights into the psychological well-being of healthcare professionals during the COVID-19 pandemic. The findings contribute to the existing literature on the subject and highlight the importance of targeted interventions and support strategies to address stress, enhance resilience, and mitigate moral distress among healthcare professionals in similar contexts.

6. Conclusion

This study sheds light on the impact of the COVID-19 pandemic on the stress, resilience, and moral distress levels of healthcare professionals in Jordan. The findings highlight the need for targeted support and interventions for vulnerable groups, such as females,

unmarried individuals, and younger professionals, to bolster their resilience and mitigate the negative effects of prolonged stress. Healthcare organizations and policymakers should be aware of the sources of stress experienced by different occupational groups to tailor support measures accordingly and promote the well-being of their frontline workers.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by King Hussein Cancer Center Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because the survey was conducted over Survey Monkey.

Author contributions

WA: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing, Formal analysis. GA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. KA: Formal analysis, Writing – review & editing. AS: Writing – review & editing. RH: Conceptualization, Methodology, Writing – review & editing. CB: Conceptualization, Methodology, Writing – review & editing. RS: Conceptualization, Methodology, Writing – review & editing. MA-r: Project administration, Resources, Validation, Writing – review & editing. AM: Project administration, Resources, Validation, Writing – review & editing. OS: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Prevalence and associated risk factors for mental health problems among young adults in Fiji Island during COVID-19: a cross-sectional study

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Introduction: The COVID-19 pandemic has had a significant impact on mental health globally. To understand the impact of the pandemic on mental health in Fiji, this study aimed to investigate the prevalence of anxiety disorder and depression among the young adults.

Method: An online survey was conducted to assess the prevalence of anxiety disorder and depression among the general population in Suva, Fiji during the COVID-19 pandemic. A total of 1,119 Fiji adults participated in the study. The study was conducted between May 20 to June 30, 2022, using a snowball sampling via social media platforms. The Generalized Anxiety Disorder (GAD-7) and Patient Health Questionnaire (PHQ-9) scales were used to measure anxiety and depression, respectively. The COVID-19 related stressors was evaluated using the adapted SARS stressors assessment. Univariate and multivariate logistic regression analysis was performed to determine the factors influencing mental health among respondents.

Results: The result shows that a significant portion of individuals experienced each of the stressors, with the highest prevalence seen for hearing information about the severity of COVID-19. The prevalence of anxiety and depression was found to be 45% and 49%, respectively. Being female, having pre-existing illness and COVID-19 stressors were a risk factor to develop anxiety and depression. On the other hand, employed individuals and having high BMI was a protective factor against developing depression during COVID-19 lockdown.

Conclusion: These findings highlight the importance of addressing the mental health needs of the Fijian population during the COVID-19 pandemic and beyond.

KEYWORDS

mental health, COVID-19, pandemic, social restrictions, Fiji, Asia-Pacific

1 Introduction

The emergence of the Coronavirus disease (COVID-19) outbreak in late 2019 marked the beginning of a global health crisis that rapidly spread across the world (1). The virus was highly contagious, leading to a significant increase in cases and deaths outside of China in March 2020. The World Health Organization declared the outbreak an epidemic in January 2020, with over 200 countries and territories reporting cases (2). The COVID-19 can be transmitted through various routes, including direct transmission through physical contact, such as coughing, sneezing, and inhaling respiratory droplets from an infected person (3). Governments around the world had implemented various measures such as home confinement, quarantine for infected individuals, social distancing, and the use of personal protective equipment, such as face masks and gloves, in an attempt to control the spread of the virus (4). However, these containment strategies, including isolation and physical confinement, have reportedly had negative impacts on mental health (5). Frequent emotions and established risk factors for various mental health disorders, including anxiety, affective, and post-traumatic stress disorders, include frustration, loneliness, and worry about the future (6).

The COVID-19 pandemic has had a disproportionate impact on various groups, leading to increased mental health difficulties (7). In particular, healthcare workers are at higher risk of contracting the virus and experiencing heightened stress (8). Individuals with low income and precarious employment face job insecurity and live in overcrowded conditions, contributing to increased stress and depression. Marginalized communities experience systematic inequalities and limited access to healthcare and social support, amplifying the psychological impact of the crisis (9). The COVID-19 pandemic has also impacted children and school going students, placing them at risk of mental health difficulties from disrupting their learning process, and hindering their acquisition of knowledge, skills, and structured routines (10). Minority and ethnic groups, facing challenges such as key worker roles, overcrowded living conditions, poverty, and discrimination, are more susceptible to mental health issues. Individuals with pre-existing physical or mental health conditions are also at higher risk of mental health difficulties during COVID-19 because of worsening symptoms for individuals with pre-existing mental health conditions (7).

Fiji reported its first case of COVID-19 in Lautoka on 19 March 2020, and as of 1 June 2023, the country has had a total of 68,921 cases and 882 deaths, spanning across all divisions (11). The COVID-19 pandemic and the measures implemented to control its spread have disrupted daily routines, caused financial stress, and increased the risk of mental health problems in Fiji, including anxiety, depression, and substance abuse. The isolation and confinement resulting from the pandemic can worsen existing mental health issues, while limited access to mental health care services exacerbates the challenges due to cultural stigma, a shortage of trained professionals, and resource constraints. The economic consequences of the pandemic have also contributed to financial stress and further impacted mental health in Fiji (12). Ensuring the mental well-being of the population in Fiji will be crucial for the country's overall recovery from the pandemic.

There is growing evidence that the COVID-19 has caused a substantial impact on mental health (13). The virus's rapid and unprecedented transmission has fueled widespread fear, uncertainty, and anxiety, intensified by constant news updates and the perceived threat of infection (6, 14). The disruptions to routine life, including work, education, and daily activities, have resulted in psychosocial challenges, causing a loss of structure, purpose, and normalcy for many individuals. Financial hardships and economic uncertainties, compounded by job losses, have further heightened stress levels and distress (15). A meta-analysis that examined 68 studies from 19 countries during the pandemic found that approximately 33% of the general population experienced symptoms of anxiety, while 30% reported symptoms of depression (15). Early in the pandemic, a study in China noted alarming figures with 29% of the population experiencing anxiety and 37.1% grappling with depression (16). A broader international study covering 78 countries reported that 50% of individuals experienced moderate mental health effects due to COVID-19 lockdowns (17). The impact extends beyond high-income countries, with studies from 40 European countries reported a significant 17.80% prevalence of distress during the pandemic (18). Importantly, lower-income countries have not been spared, as evidenced by studies highlighting a higher prevalence of mental health issues during COVID-19 in low and lower-middle-income countries (19). The Asia-Pacific region, a diverse area with varied socio-economic landscapes, has consistently reported elevated levels of anxiety, depression, and stress during the pandemic (20). Specific attention has been drawn to Pacific Island countries, such as New Zealand, where a couple of studies have reported a higher proportion of psychological disturbances during COVID-19, shedding light on the unique challenges faced by these communities (21–23). Notably, there is a significant gap in studies on mental health during COVID-19 in Fiji Island underscores a broader issue of underrepresentation from certain regions, limiting the holistic understanding of the pandemic's mental health impact.

The sharp rise in these mental health symptoms underscores the unique challenges and psychological distress caused by the pandemic. Studies reported that various factors associated with this increased susceptibility to psychological consequences during COVID-19 (15). The findings from recent studies indicate that certain demographic factors and risk factors are associated with a higher prevalence of mental health consequences. Specifically, females, younger age groups (24), individuals with lower socioeconomic status (SES) (25, 26), those residing in rural areas (27), people with preexisting illness (24), frequent alcohol-consumers (28), smokers (28), and individuals at higher risk of COVID-19 infection (29) and COVID-19 related stressors (30) are more likely to experience negative mental health.

While a substantial body of research has examined the impact of the COVID-19 pandemic on mental health globally (31–33), there is a significant dearth of systematic assessments specifically tailored to the Pacific Island context, particularly in Fiji. Much of the existing literature predominantly stems from studies conducted in diverse cultural and socioeconomic settings, potentially limiting its applicability to the unique circumstances of Pacific Island nations. The experiences of the researcher reveal a critical gap in understanding the mental health outcomes of individuals in Fiji during the ongoing pandemic. Unlike many developed nations, Fiji faces distinctive challenges, including limited mental health resources, unique cultural contexts, and vulnerability to external stressors (34). While one study conducted among 300 physical education and sports teachers in Fiji

found that 50% of them were negatively affected by the pandemic (12), there was no research conducted on the broader population. Further, there is a pressing need for research that delves into the nuanced mental health experiences of the broader Fijian population during COVID-19, as existing interventions and findings may not be directly translatable to this specific cultural and regional context. Our study aims to address this gap by providing a focused examination of mental health outcomes in Fiji during the pandemic, contributing vital insights to the broader understanding of the pandemic's impact on mental health in Pacific Island nations.

Nevertheless, it is important to recognize that negative psychological consequences were already evident in pacific region (35) and Fiji prior to the pandemic (34), and the COVID-19 situation has likely exacerbated these challenges. Fiji, like many other countries, has faced social and economic disruptions, health concerns, and increased stress levels due to the pandemic. The lack of systematic assessment of mental health outcomes among the general population in Fiji highlights the need for further research to understand the specific impact of the pandemic on mental health in the country. Therefore, this study investigated the mental health problems among different group of populations during the early stage of the COVID-19 pandemic in Fiji. We also aimed to examine the risk factors associated with developing these psychological problems, among general populations in Fiji.

2 Methods

2.1 Study design and data collection

An online survey was conducted to gather data on the impact of the COVID-19 pandemic on mental health in Suva, Fiji. The survey was conducted from May 20 to June 30, 2022, after the second wave of the lockdown. The target participants for the study were aged 18 or over, living in the Fiji during the survey. A total of 1,119 Fiji adults participated in the study. The sample was collected using the snowball sampling method, in which the survey was distributed through social networks such as Facebook, WhatsApp, LinkedIn, and Instagram. To design the questionnaire, we used Kobo Toolbox to create an online survey that could be accessed through a link. This allowed for easy data collection and visualization. The link for the survey was shared with the target group in two primary ways: (1) by emailing an invitation to participate to all students attending the University of the South Pacific and (2) by using field assistants to distribute the survey link to the target group.

2.2 Measurement instrument

2.2.1 COVID-19 stress

The COVID-19 related stressors utilized in this study was adapted from the 10-item SARS stressors scale (36). It included seven questions related to COVID-19 infection, quarantine status, the severity of contagiousness, vacation and financial loss. Respondents answered each item as either yes or no, with a score of 1 or 0, respectively. The scores for all items were then summed to calculate an overall score, with higher scores indicating a greater amount of stress related to COVID-19.

2.2.2 Mental health measures

To assess anxiety levels, we used the Generalized Anxiety Disorder 7-item (GAD-7) scale (37). This scale has excellent validity and reliability, with a Cronbach's alpha coefficient of 0.911. Respondents indicate the frequency of symptoms over the past two weeks on a 0 (not at all) to 3 (almost every day) scale. A summary score is calculated by summing all items, with a range of 0 to 21. Respondents are categorized as having minimal/no anxiety (summary scores between 0–4), mild anxiety (5–9), moderate anxiety (10–14), or severe anxiety (15–21). In addition to these four levels of anxiety, we used a cutoff score of 9 or higher to identify clinical levels of generalized anxiety disorder (38).

To measure respondents' levels of depression over the past two weeks, we used the Patient Health Questionnaire (PHQ-9). This well-validated tool has a Cronbach's alpha coefficient of 0.89 and includes nine items that are rated on a 0 (not at all) to 3 (almost every day) scale (39). Scores are calculated by summing the items, with a range of 0 to 27. Scores of 0–4 indicate minimal to no depression, 5–9 mild depression, 10–14 moderate depression, and scores of 15–21 indicate severe depression (40). We used these four levels of depression, as well as a cutoff score of 10 or higher, to identify clinical levels of major depressive disorder (41).

2.2.3 Risk factors

Sociodemographic variables including age, gender, level of education attained, living area, area of residence, current living status, occupations and monthly income were self-reported. Gender was determined by asking whether male or female or other. Age was used as a continuous variable. The education level of the participants was categorized into following groups including college, undergraduate and postgraduate level. Living region was assessed by identifying their region as Central, Northern, Eastern or Western. Residents' characteristics were determined by their present residence, which was classified as urban or rural. Three questions were used to assess respondents' living status, including whether they lived with or without family members or alone. Occupation were classified as unemployed, student, government job, private job, healthcare workers, teacher, business, daily labor worker, and housewife. Monthly income was classified as 0–2,000 or 2,001–4,000 or > 4,000 FJD.

In terms of health related variables, presence of a pre-existing illness, smoking habit, habit of drinking alcohol and kava, Body Mass index (BMI), self-reported health status and daily time spent for searching COVID-19 information were considered. Participants were asked if they have any long-standing illness or disability. BMI and daily time spent searching for COVID-19 information were recorded as continuous variables. Smoking and alcohol/kava consumption were determined by asking participants to indicate "yes" or "no".

2.3 Data analysis

In our study, we used descriptive statistics to summarize the demographic characteristics of the respondents. We reported categorical data as percentages and continuous data as means and standard deviations. To check for data normality, we used the Shapiro–Wilk test. Since our data were not normally distributed, we used non-parametric tests to investigate the relationships between the respondents' general characteristics and their mental health during the COVID-19 pandemic. To identify potential predictors of

psychological outcomes, we conducted univariate (unadjusted) and multivariable (adjusted) logistic regression analysis, adjusting for sociodemographic factors. In the univariate analysis, we employed chi-squared tests or the Kruskal-Wallis test to assess the association between potential risk factors and psychological outcomes. Since we used cut-off values for outcome variables such as anxiety (≥10) and depression (≥10), we conducted multivariable logistic regression analysis after adjusting for sociodemographic, heath and COVID-19 stressors. We included only statistically significant predictors from the univariate analysis in the multivariable logistic regression models and calculated adjusted coefficients and their 95% confidence intervals for independent variables. We considered a two-tailed test with a significance level of $p < 0.05$ to be statistically significant. SPSS statistical software (version 26) was used to analyse the data.

2.4 Ethical approval consideration

The study followed the process of the Declaration of Helsinki and maintained the highest possible extent of ethical standards. The study included a clear description of the procedures followed to obtain informed consent from participants, including the purpose of the study, the voluntary nature of participation, and any necessary ethical approvals obtained from relevant institutional review boards or ethics committees. An electronic consent of participation was obtained from all the respondents before they took part in the study. The consent form is attached to the questionnaire. The study was approved by the ethical clearance committee of the School of Information Technology, Engineering, Mathematics and Physics (STEMP) Academic Unit Research Committee, University of South Pacific, Fiji.

3 Results

3.1 Demographic and health-related characteristics

Table 1 presents data on the sociodemographic and health-related characteristics of a group of respondents in Fiji. The majority of the respondents were female (59.8%), with a mean age of 26.01 years. In comparing our convenience sample to the known population parameters from the Fiji census, we observed slight variations in the age and gender distribution. The Fiji census data 2017 indicated that the median age of the population was 27.5 years, which means that half of Fiji's population was below that age Additionally, the gender distribution was approximately 49% male and 51% female (42). There was a slight difference in the age distribution, with our sample having a slightly lower proportion (mean age: 26.01) compared to the population parameters. The gender distribution in our sample was also slightly different, with a higher percentage of females (59.8%).

Most of the respondents were single (79.0%) and lived with their family members (81.0%). The majority of the respondents were students (63.0%), and enrolled in undergraduate education (59.0%). Most of the respondents lived in urban areas (81.9%) and had a monthly income of 0–2000 FJD (55.1%). In terms of health-related variables, only 9.1% of the respondents reported having a pre-existing illness. A small percentage of respondents reported engaging in smoking (13.2%) or drinking alcohol (17.4%) or drinking kava (17.1%). The mean body mass index (BMI) of

TABLE 1 Demographic characteristic of the respondents (*N* = 1,119).

Features	*N*	Percentage (%), mean (SD)
Gender		
Male	445	39.8
Female	669	59.8
Non-binary or prefer not to say	5	0.4
Age (years)	1,119	26.01 (9.44)
Marital status		
Single	884	79.0
Married	215	19.2
Divorced	20	1.8
Education		
College or below	73	6.5
Undergraduate	660	59.0
Postgraduate or above	386	34.5
Place of residence		
Rural	203	18.1
Urban	916	81.9
Occupation		
Unemployed	51	4.6
Student	705	63.0
Employed	363	32.4
Living status		
Living alone	76	6.8
Living with family members	906	81.0
Living non-family members	137	12.2
Monthly family income (FJD)		
0–2,000	617	55.1
2,001–4,000	229	20.5
>4,000	273	24.4
Having pre-existing illness		
No	1,017	90.9
Yes	102	9.1
Habit of smoking		
No	971	86.8
Yes	148	13.2
Habit of drinking alcohol		
No	907	81.1
Yes	212	18.9
Habit of drinking kava		
No	928	82.9
Yes	191	17.1
Body mass index (BMI)	1,119	25.77 (5.9)
Perceived health status		
Poor	168	1.6
Fair	211	18.9
Good	478	42.7
Very good	245	21.9
Excellent	167	14.9
Time spent for COVID-19 (h/day) information	1,119	3.45 (3.17)

the group was 25.77. In terms of perceived health status, 42.7% of the respondents reported being in good health, while 25.5% reported being in fair or poor health. The mean time spent searching for COVID-19 related information was 3.45 h per day.

3.2 COVID-19 stressors

Figure 1 presents data on the prevalence of different COVID-19 specific stressors experienced by individuals. The figure includes data on seven different stressors: having family members suspected of having COVID-19, having a close friend recently diagnosed with COVID-19, knowing someone who has COVID-19 symptoms, fear of getting quarantined, hearing information about the severity of COVID-19, cancelling a vacation trip because of COVID-19, and experiencing income loss because of COVID-19.

The figure shows that a significant portion of individuals experienced each of the stressors, with the highest prevalence seen for hearing information about the severity of COVID-19 (92%), knowing someone who has COVID-19 symptoms (84%), cancelling a vacation trip because of COVID-19 (73%) and having a close friend recently diagnosed with COVID-19 (72%).

3.3 Overall prevalence of poor mental health

Figure 2 presents data on the prevalence of mental health issues among the general population in Fiji during the COVID-19 pandemic. For generalized anxiety, 28% of the general population had minimal levels of anxiety, 26% had mild levels, 24% had moderate levels, and 21% had severe levels. For depression, 28% reported minimal depression levels, 23% experienced mild depression, 16% had moderate depression levels, and 33% reported severe depression levels.

3.4 Prevalence of poor mental health by professions

Table 2 shows the prevalence of mental health among different groups of occupation. The prevalence of depression was significantly different between the unemployed (41.2%), students (47.2%), and employed (42.4%). No other differences between groups were detected.

3.5 Factors influencing the prevalence of poor mental health

Table 3 presents the univariate and multivariate results for the risk factors for anxiety and depression. Gender, having pre-existing illness, and COVID-19 stress were significant predictors for experiencing anxiety. In particular, female respondents had a significantly increased risk of experiencing anxiety disorder (OR = 1.88 95% CI = 1.42–2.48, $p < 0.001$) than their counterparts. Respondents with a pre-existing illness were more likely to experience anxiety disorder (OR = 1.89, 95%CI = 1.19–3.01, $p < 0.01$). Further, respondents who had experienced higher COVID-19 stress during pandemic period were more likely to experience anxiety disorder (OR = 1.22, 95%CI = 1.13–1.32, $p < 0.001$).

Similarly, gender, occupation, BMI, and COVID-19 stress were significant factors related to depression. Female respondents had a greater risk of experiencing depression (OR = 1.35 95% CI = 1.02–1.77, $p < 0.05$) than their counterparts. Respondents who experienced higher COVID-19 stress were more prone to experience depression (OR = 1.23, 95%CI = 1.12–1.30, $p < 0.001$). However, employed individuals (OR = 0.43 95%CI = 0.19–0.97, $p < 0.05$), and those had a high BMI (OR = 0.97, 95%CI = 0.95–0.98, $p < 0.5$) were less likely to experience depression (Table 3).

4 Discussion

4.1 Summary of main findings

In Fiji, mental health issues have been a growing concern for many years, with limited resources and access to mental health services for the general population (43). The COVID-19 pandemic exacerbated this issue, with a significant portion of the population experiencing mental health challenges such as anxiety and depression. The pandemic also resulted in unprecedented changes in daily life, including lockdowns, social distancing, and travel restrictions. It not only posed a significant threat to physical health but also had a

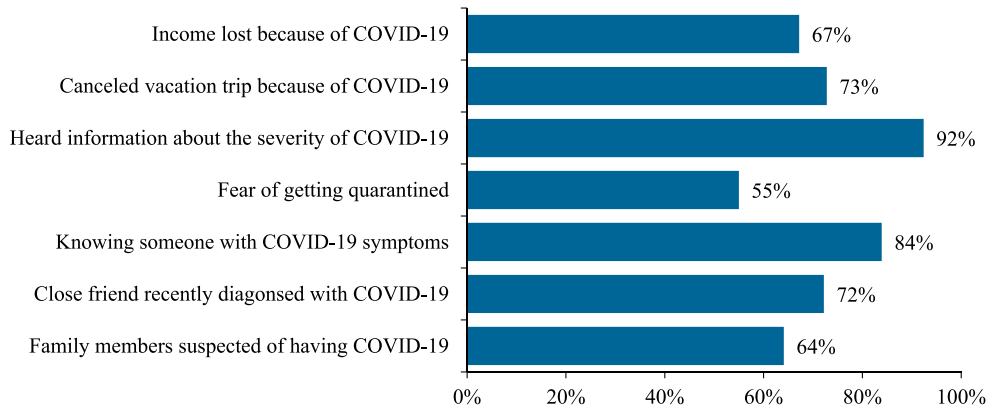

FIGURE 1
COVID-19 specific stresses among respondents (N = 1,119).

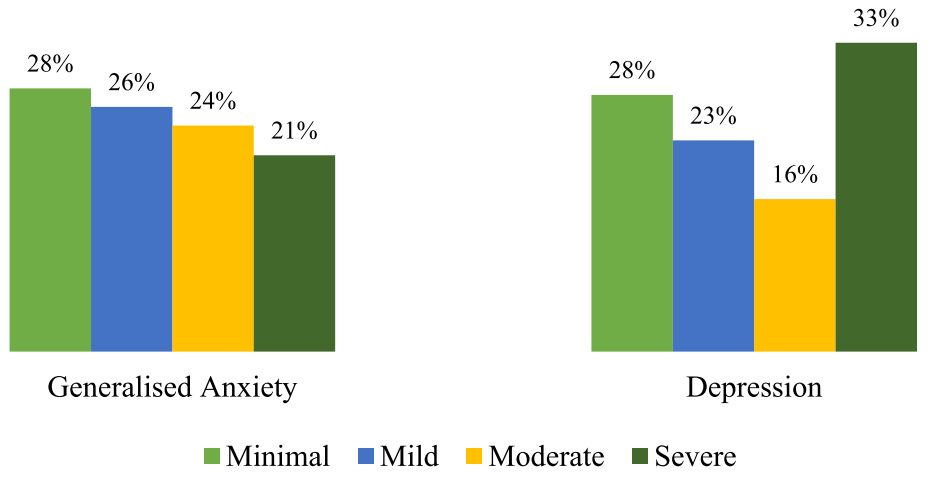

FIGURE 2
Overall prevalence of poor mental health (*N* = 1,119).

TABLE 2 **Prevalence of poor mental health by profession (*N* = 1,119).**

Occupation	Anxiety (%)	95% CI	Depression (%)	95% CI
Unemployed	41.2	27.2–55.16	49.02	34.82–63.22
Student	47.2	43.54–50.93	54.33	50.64–58.01
Employed	42.4	37.32–47.53	49.6***	35.42–45.57

*** $p < 0.001$; anxiety cutoff score: ≥10; depression cutoff score: ≥10.

substantial impact on mental health. Addressing mental health impacts during lockdown periods in Fiji was limited. The current study of 1,119 Fiji young adults determined prevalence and risk factors of poor mental health during the pandemic.

Our findings suggest that a significant portion of the young adults in Fiji experienced mental health issues, with higher levels of severity seen for depression than generalized anxiety. Given the scarcity of existing national study on the impact of COVID-19 on mental health in Fiji, we have compared our study findings with other countries. A similar finding was observed in young adults in New Zealand during the COVID-19 outbreak (44). Studies from around the world have consistently reported an increase in mental health issues including depression, anxiety, and stress during the pandemic due to various stressors such as isolation, fear of infection, financial difficulties, and loss of loved ones (45, 46). Interestingly, we found that students consistently showed the highest rates of depression, followed closely by the unemployed and then the employed. Previous studies also reported that students were highly susceptible to developing mental health than working professionals during COVID-19 (47). Students faced significant disruptions in their education during the COVID-19 pandemic, including the shift to online learning, which often introduced new challenges and stressors (48). The uncertainty of the academic environment and the need to adapt to remote learning can contribute to increased anxiety and depression among students (49). Students often faced uncertainty about the future, including concerns about job prospects, internships, or the continuation of their education that could lead to depression (50). Our study also suggests that COVID-19 had a significant impact on individuals and caused a range of related stressors among the adult population in Fiji. Similar findings were observed in other developing countries like India (51) and Bangladesh (47). It's important to consider the potential impact of these stressors on mental health and to address the needs of individuals who have experienced them.

Our findings suggest that female respondents had a significantly increased risk of experiencing anxiety disorder and depression than their counterparts. This finding is in line with previous research that has shown that women are more likely to experience anxiety disorders and depression than men (52–54). Such gender differences may correspond to women being more affected by the social and economic consequences of the pandemic than men on average (55). For instance, school closures and family members becoming unwell may result in additional caregiving responsibilities for women. Women are also more likely to be financially disadvantaged during the pandemic due to lower salaries, less savings, and less secure employment than men (56, 57). As a result, women may be more vulnerable to financial stress and insecurity, which can increase the risk of developing mental health disorders (58). Furthermore, the prevalence of domestic violence has increased during periods of lockdown and stay-at-home orders, with women being more likely to be victims of such violence (59). The pandemic has exacerbated existing gender inequalities and increased the burden of caregiving and household responsibilities, which may contribute to the higher prevalence of mental health disorders among women (57). Other reasons could be biological mechanisms such as that there are hormonal differences between males and females that affect the way they respond to stress. Research has shown that women tend to have higher levels of stress hormones like cortisol and may be more sensitive to the effects of these hormones on their bodies and brains (60).

Having a pre-existing illness was a risk factor to develop anxiety disorder during the pandemic in Fiji. These findings were consistent

TABLE 3 Influencing factors of mental health in Fiji during COVID-19.

Features (total *N*)	Anxiety disorder			Depression		
	N (%)	Univariate analysis, χ^2	Multivariate analysis, OR (95% CI)	*N* (%)	Univariate analysis, χ^2	Multivariate analysis, OR (95% CI)
Gender		**20.77*****			**8.19****	
Male (445)	165 (37.1)		Ref.	198 (44.5)		Ref.
Female (669)	340 (50.8)		**1.88 (1.42–2.48)*****	353 (52.8)		**1.35 (1.02–1.77)***
Non-binary or prefer not to say (5)	3 (60.0)		1.91 (0.29–12.36)	4 (80.0)		2.89 (0.30–27.55)
Age (years) (1119)	25.47 (±7.90)	**3.95***	1.00 (0.98–1.02)	25.17 (±8.01)	**12.82*****	1.00 (0.97–1.01)
Marital status		**5.37***			**8.18****	
Single (884)	418 (47.3)		Ref.	459 (51.9)		Ref.
Married (215)	78 (36.3)		0.70 (0.47–1.05)	83 (38.6)		0.77 (0.51–1.15)
Divorced (20)	12 (60.0)		2.08 (0.78–5.56)	13 (65.0)		2.35 (0.83–6.57)
Education		0.026			0.002	
College or below (73)	32 (43.8)		Ref.	29 (39.7)		Ref.
Undergraduate (660)	303 (45.9)		1.10 (0.62–1.93)	340 (51.5)		1.70 (0.95–3.03)
Postgraduate or above (386)	173 (44.8)		1.28 (0.71–2.32)	186 (48.2)		2.30 (1.24–4.24)
Place of residence		2.03			0.068	
Rural (203)	83 (40.9)		Ref.	99 (48.8)		Ref.
Urban (916)	425 (46.4)		1.23 (0.87–1.74)	456 (49.8)		0.91 (0.64–1.28)
Occupation		1.20			**13.05*****	
Unemployed (51)	21 (41.2)		Ref.	25 (49.0)		Ref.
Student (705)	333 (47.2)		1.12 (0.60–2.12)	383 (54.3)		1.04 (0.55–1.96)
Employed (363)	154 (42.4)		0.91 (0.41–2.02)	25 (36.2)		**0.43 (0.19–0.97)***
Living status		2.19			2.35	
Living alone (76)	37 (48.7)		Ref.	40 (52.6)		Ref.
Living with family members (906)	396 (43.7)		0.76 (0.45–1.28)	434 (47.9)		0.66 (0.38–1.12)
Living non-family members (137)	75 (54.7)		1.14 (0.62–2.12)	81 (59.1)		0.97 (0.51–1.80)
Monthly family income (FJD)		**9.22****			3.13	
0–2,000 (617)	306 (49.6)		Ref.	319 (51.7)		Ref.
2,001–4,000 (229)	93 (40.6)		0.70 (0.50–0.97)	113 (49.3)		1.05 (0.75–1.46)
>4,000 (273)	109 (39.9)		0.72 (0.52–0.99)	123 (45.1)		0.81 (0.59–1.11)
Having pre-existing illness		**3.63*****			**14.61*****	
No (1017)	444 (43.7)		Ref.	486 (47.8)		Ref.
Yes (102)	64 (62.7)		**1.89 (1.19–3.01)****	69 (67.6)		1.97 (1.21–3.19)
Habit of smoking		1.45			2.86	
No (971)	434 (44.7)		Ref.	472 (48.6)		Ref.
Yes (148)	74 (50.0)		1.31 (0.86–1.99)	83 (56.1)		1.46 (0.95–2.23)
Habit of drinking alcohol		0.53			0.34	
No (907)	407 (44.9)		Ref.	446 (49.2)		Ref.

(Continued)

TABLE 3 (Continued)

Features (total *N*)	Anxiety disorder			Depression		
	N (%)	Univariate analysis, χ^2	Multivariate analysis, OR (95% CI)	*N* (%)	Univariate analysis, χ^2	Multivariate analysis, OR (95% CI)
Yes (212)	101 (47.6)		1.03 (0.71–1.50)	109 (51.4)		1.08 (0.73–1.57)
Habit of drinking kava		0.07			1.14	
No (928)	423 (45.6)		Ref.	467 (50.3)		Ref.
Yes (191)	85 (44.5)		0.87 (0.58–1.30)	88 (46.1)		0.70 (0.46–1.05)
Body mass index (BMI) (1119)	25.71 (±5.91)	0.24	0.99 (0.97–1.02)	25.47 (±5.98)	**4.00***	**0.97 (0.95–0.98)***
Perceived health status		**19.04*****			**32.65*****	
Poor (168)	12 (66.7)		Ref.	12 (66.7)		Ref.
Fair (211)	117 (55.5)		0.75 (0.25–2.26)	127 (60.2)		1.14 (0.38–3.40)
Good (478)	219 (45.8)		0.54 (0.18–1.59)	254 (53.1)		0.80 (0.27–2.35)
Very good (245)	101 (41.2)		0.49 (0.16–1.48)	103 (42.0)		0.54 (0.18–1.63)
Excellent (167)	59 (35.3)		0.41 (0.13–1.27)	59 (35.3)		0.42 (0.13–1.28)
Time spent for COVID-19 (h/day) information (1119)	3.67 (±3.17)	**7.73****	1.04 (1.00–1.08)	3.48 (±3.08)	0.99	1.00 (0.95–1.04)
COVID-19 stress (1119)	5.40 (±1.55)	**29.46*****	**1.22 (1.13–1.32)*****	5.34 (±1.57)	**23.65*****	**1.20 (1.12–1.30)*****

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; bold are significant value; anxiety cutoff score: ≥10; depression cutoff score: ≥10.

with previous studies (61–63). People with pre-existing health conditions may be at higher risk of developing severe COVID-19 symptoms, which can increase anxiety and fear about their health and wellbeing. They may worry about the potential consequences of contracting COVID-19 and the impact it could have on their health and ability to manage their existing illness (64). Further, people with chronic illnesses may have more limited access to healthcare services during the pandemic, which can lead to increased anxiety about their ability to manage their illness and access the care they need. The pandemic has disrupted healthcare systems and forced many people to delay or forego medical appointments, which can exacerbate feelings of uncertainty and anxiety (65).

Our study suggests that higher COVID-19 stress was a risk factor to develop anxiety and depression. In this study, having family members or a close friend or knowing someone suspected of COVID-19, hearing information about the severity of COVID-19, cancelling a vacation trip because of COVID-19, and experiencing income loss because of COVID-19 was the major COVID-19 stress that elevated respondents' risk of anxiety and depression. These findings are consistent with earlier studies (66, 67). Unemployment, for instance, can lead to financial insecurity and a sense of loss of control over one's life, both of which are known risk factors for depression and anxiety (68). The death of a loved one or friend due to COVID-19 can also cause intense grief and distress, leading to the development of these mental health conditions. Receiving a positive COVID-19 diagnosis can also cause fear and uncertainty about one's health and the health of others, which can lead to anxiety symptoms. Further, individuals may have been worried about their family members getting infected by the virus. This was especially true for working professionals who had to return to their workplaces during the pandemic, such as healthcare workers who were more susceptible to exposure and could transmit the virus to their families (69). Research found that participants whose family members worked in healthcare were 44% more likely to develop mental illness (70). The perceived risk of contracting or transmitting the virus to family members contributed to increased stress and anxiety among workers.

Interestingly, our findings found that employed individuals were protective against depression during lockdowns. Employed individuals typically have a source of income and financial stability. This financial security can reduce the stress associated with economic uncertainty, which is a common trigger for depression, especially during economic downturns (71, 72). One study conducted in Turkey found that state employees experienced lower levels of anxiety and depression compared to those in private sectors (73). Further, employees in Fiji may have had access to better resources and support systems during the pandemic, which could have contributed to their better mental health outcomes. For example, government employees may have had access to mental health services through their employee assistance programs, as well as job protections and financial support during the pandemic. However, further research is needed to confirm this finding and explore potential explanations for this relationship.

High BMI was associated with less depression in our study. High BMI being considered a protective factor might seem counterintuitive, especially given the common perception of high BMI as an adverse health outcome. It's crucial to note that the relationship between BMI and health outcomes can be complex and context-dependent. While high BMI is generally associated with

increased health risks (74), in certain populations or contexts, it may indeed be linked to better health outcomes. One theoretical rationale for high BMI being perceived as protective, particularly in some low-income populations, could be related to the "obesity paradox." This phenomenon suggests that, in certain conditions such as chronic diseases or in older age groups, individuals with a higher BMI might have a survival advantage compared to those with a lower BMI. This paradox has been observed in a previous study where overweight groups exhibited the lowest prevalence of depression (75). It is often attributed to factors like better nutritional reserves, increased energy stores, and potential protective effects in the face of certain health challenges. Further, it is well established that physical activity is beneficial for mental health, and individuals with a higher BMI may be more likely to involve in weight-gain protective behavior (76). Physical activity has also been shown to have a positive impact on the immune system, which may be particularly relevant during a pandemic.

4.2 Implications of the study

Our study findings have important implications. The high prevalence rates of anxiety disorder and depression underscore the critical need for strengthened mental health support services in Fiji, especially during public health crises like the COVID-19 pandemic. Investing in accessible and culturally sensitive mental health resources can aid in addressing the immediate mental health needs of the population (77). Our study findings underscore the need for targeted public health interventions to address mental health challenges in Fiji, particularly among vulnerable groups such as students, females, and individuals with pre-existing illnesses. Implementing support programs that address the specific needs and challenges faced by these populations can contribute to more effective mental health outcomes. Community-based mental health programs should be considered to foster a supportive environment. These programs can engage community leaders, local organizations, and individuals to create a network of mental health support, reducing stigma and promoting open conversations about mental well-being (78). Understanding the generational impact of mental health, policymakers should focus on long-term resilience-building measures. Incorporating mental health education in schools, workplaces, and community settings can contribute to a more resilient and mentally healthy future population (79). However, our findings should be interpreted with caution. Generalizing to rural populations or those with different socio-economic and cultural backgrounds should be approached with caution. Fiji's diversity may result in varied responses to stressors and different prevalence rates. Extrapolating findings to populations outside Fiji, especially in vastly different cultural and socio-economic contexts, may not be appropriate. The uniqueness of Fiji's circumstances necessitates careful consideration when applying these findings to dissimilar settings.

4.3 Limitations of the study

The participants were recruited through convenience sampling, which may limit the generalizability of the findings to the larger population in Fiji. The study participants were also recruited through social media, which may result in a self-selection bias. The data collected in this study was based on self-reported measures, which may be subject to recall bias, social desirability bias, and other sources of response bias. The study used a cross-sectional design, which limits the ability to draw causal inferences between the COVID-19 pandemic and mental health outcomes. Longitudinal studies would be necessary to assess the temporal relationships between exposure to the pandemic and mental health outcomes. Further, we adapted the SARS-10 scale for assessing COVID-19 stressors was influenced by the historical context and the imperative for a validated instrument at the onset of our study. During that period, there was no well-established COVID-19 stressor scale. Further, the SARS-10 scale stood as a well-established and widely recognized tool for evaluating stressors related to infectious disease outbreaks. The study relied on self-reported symptoms of depression and anxiety, rather than clinical diagnoses made by healthcare professionals. Further, the study did not collect information on COVID-19 exposure, such as whether participants had contracted the virus or had close contacts who did, which may be an important factor in understanding mental health outcomes during the pandemic.

5 Conclusion

In conclusion, it is imperative to delve deeper into the implications of the study findings and consider the broader context for mental health interventions in Fiji. The substantial prevalence rates of anxiety disorder and depression uncovered in this study underscore the urgent need for targeted mental health interventions tailored to the unique challenges faced by the general population in Suva, Fiji. The prevalence rates, particularly the high prevalence related to hearing information about the severity of COVID-19, emphasize the pervasive impact of pandemic-related stressors on mental well-being. Moreover, the identified risk factors, such as being female, having a pre-existing illness, and exposure to COVID-19 stressors, provide critical insights into the specific demographic and contextual elements that amplify the vulnerability to anxiety and depression. These risk factors should guide the development of interventions that address the distinct needs of these at-risk groups. Conversely, the protective factors identified, including employment status and higher BMI, present valuable opportunities for targeted mental health support strategies. Recognizing the potential resilience conferred by employment and certain health characteristics can inform interventions designed to bolster mental well-being in these specific segments of the population. These findings serve as a foundation for evidence-based mental health initiatives in Fiji during future public health crises. The identified risk and protective factors should be integrated into public health strategies, with a focus on proactive and accessible mental health support systems. Policymakers and healthcare professionals can leverage this knowledge to implement interventions that not only address the current challenges but also fortify mental health resilience for the future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by School of Information Technology, Engineering, Mathematics and Physics (STEMP) Academic Unit Research Committee, University of South Pacific, Fiji. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MK: Conceptualization, Funding acquisition, Methodology, Writing – review & editing. MP: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. KM: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – review & editing. AC: Conceptualization, Data curation, Methodology, Writing – review & editing. KE: Conceptualization, Data curation, Writing – review & editing. KP: Conceptualization, Data curation, Writing – review & editing. MB: Conceptualization, Methodology, Writing – review & editing. CP: Conceptualization, Methodology, Writing – review & editing. FS: Conceptualization, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Telepresence robots as facilitators of physical exercise during COVID-19: a feasibility and acceptance study

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The COVID-19 pandemic and associated restrictions on mobility and access to green space have disrupted exercise habits worldwide. According to the World Health Organization (WHO), approximately 1.4 billion adults were insufficiently physically active in 2016, with detrimental impacts on health. The proposed study investigated the use of telepresence-robot-based personal trainers to facilitate remote exercise during the pandemic-related lockdowns. Several adults aged 18–65 were recruited for a four-week intervention and thorough research investigation. The intervention involved one-hour outdoor exercise sessions held three times per week in a local park with a human instructor connected via a telepresence robot. Surveys assessed perceptions of social presence, usability, the intention to use the robot and the psychological benefits of access to green space. System logs tracked participation and technical errors. At baseline, 30% of the participants met the WHO physical activity (PA) recommendations, compared to 80% after the intervention. The study shows significant increases in many parameters. These are perceived in social presence ($p < 0.021$), usability ($p < 0.04$), intentions for long-term use ($p < 0.05$), and the mental health benefits of accessing green spaces ($p < 0.013$). Attendance was found to be 90%, with a 7% technical failure rate. This investigation demonstrates the promise of telepresence robots for safely providing remote access to green spaces. They can be used to facilitate exercise during public health crises, overcoming the barriers to maintaining PA.

KEYWORDS

COVID-19, physical exercise, telepresence robots, mental health, public health

1. Introduction

1.1. Background

The COVID-19 pandemic profoundly impacted populations worldwide, necessitating restrictive public health measures to curtail viral transmission, which disrupted daily living. Mobility restrictions, social distancing, lockdowns, and the closure of parks and recreation facilities have presented formidable barriers to maintaining physical activity (PA) participation during this crisis (1). Physical inactivity was already a global issue before COVID-19, with the World Health Organization (WHO) estimating in 2016 that 1.4 billion adults failed to meet the recommended PA levels, making it one of the leading risk factors for mortality and fueling the rising prevalence of noncommunicable diseases (2). The COVID-19 pandemic has only

exacerbated this problem, with early studies showing dramatic declines in PA during the initial lockdowns, including a 48% reduction in sports participation and a 58% decrease in outdoor exercise compared to pre-pandemic levels (3). Smartphone step count data from the past 12 months indicate that the average daily steps were consistent between June 2019 and May 2020. However, there was a noticeable drop of approximately 2,500 steps per day during April and May 2020, as illustrated in Figure 1.

These trends are concerning given the well-established physical and mental health benefits of regular PA. Physical inactivity is associated with a higher risk of cardiovascular disease, diabetes, cancer, and all-cause mortality, accounting for an estimated 5 million deaths worldwide each year (4). Exercise confers protection against chronic illnesses by impacting weight management, blood pressure, insulin sensitivity, lipid profiles, immune function, and inflammation (5). Additionally, PA has demonstrated antidepressant and anxiolytic effects, which can mitigate the adverse psychological effects of isolation, grief, stress, and sedentary behavior during prolonged lockdowns (6). However, realizing these multifaceted health benefits hinges on having the motivation, resources, and access to maintain routine exercise, which COVID-19 constraints have severely limited.

While the resumption of standard PA patterns is anticipated post-pandemic, the crisis highlights the need for technologies that facilitate remote exercise, as well as access to recreation spaces, when mobility is disrupted. Virtual fitness solutions have burgeoned but require more key social dimensions and environmental engagement. In contrast, telepresence robots, which enable remote embodied interactions through a movable videoconferencing display, offer a novel approach to overcoming barriers to active lifestyles during public health emergencies. Telepresence robots have been effectively utilized in healthcare applications (7), but their use to promote PA and access to nature still needs to be explored.

Pilot initiatives before the pandemic provided initial evidence that telepresence robots could enable immersive park experiences. For example, Double Robotics and California State Parks successfully trialed remote park exploration via telepresence robots, allowing people to hike trails and interact with rangers Double Robotics (8). Such an environmental telepresence could mitigate some of the psychological harms of isolation from green spaces, which have well-documented restorative benefits for mental health and cognition (9). Additionally, previous research found that robots can enhance exercise motivation and performance. When paired with a virtual avatar coach, people spent more time running and reported greater enjoyment (10). Telepresence robots may have similar motivational effects while increasing perceived social presence and engagement.

The main contributions of the proposed investigation are as follows:

- Emerging evidence warrants further inquiry into the feasibility of using telepresence robots to facilitate remote PA within natural environments from which people are excluded during public health crises;
- We quantitively evaluate this novel application's acceptance, experience, and effectiveness, informing design optimizations for long-term viability;
- Elucidating how the environmental and social telepresence afforded by an embodied robotic platform can enhance adherence, autonomy, and psychological responses to exercise could guide technological development and policy related to remote active lifestyles;
- The proposed study was devised to provide an initial systematic investigation of telepresence robots as tools with which to foster increased PA amidst the unprecedented constraints of the COVID-19 pandemic and the protracted periods of physical inactivity it caused.

1.2. Literature review

The COVID-19 pandemic has created an urgent need to find solutions that can support the maintenance of regular physical activity amidst constraints on mobility and access to exercise facilities. A growing body of literature across diverse fields, including human-robot interactions, telehealth, exercise science, the psychology of motivation, and environmental health, has investigated the applications of telepresence robotics that allow for remote embodied interactions as potential tools to overcome the barriers to active lifestyles imposed by public health crises. This review synthesizes the key findings on user acceptance and experiences with telepresence

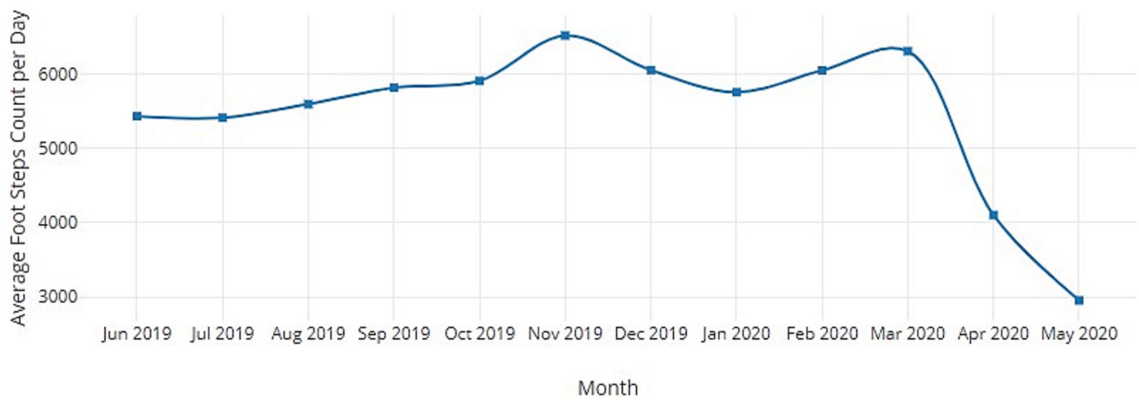

FIGURE 1
Physical activity of an average human for pre and post COVID-19.

robots in healthcare and education, embodiment factors influencing human-robot exercise engagement, the effects of virtual coaches and social facilitation on motivation, and the benefits of simulated natural environments for wellbeing.

Several studies have identified essential considerations around usability, navigation, and control interfaces that broadly influence the acceptance and adoption of telepresence robots (11–14), which can inform device optimization in exercise contexts. Smooth maneuverability and camera operations impacted the perceived ease of use and the intention to employ healthcare telepresence robots (15). Difficulties with low-level control reduced the acceptance of a hospital delivery robot by staff (16). On the other hand, a homecare robot was perceived as valuable and satisfactory when the controls enabled safe and effective navigation (17). These findings highlight the need to refine exercise telepresence robots' movement and camera controls to ensure seamless remote mobility.

Additionally, trust-mediated acceptance and willingness to rely on healthcare robots emphasize the importance of careful technical management to maximize uptime and minimize failures (18). The perceived sociability of the robot's appearance and etiquette capabilities also led to better user evaluations (19, 20). Implementing humanlike cues and socially appropriate communication aligned with exercise norms could improve engagement. Several studies have evaluated telepresence robots' abilities to enhance social connection and communication in medical and academic settings, demonstrating their viability for improving access and psychological outcomes in remote service delivery. In healthcare contexts, social telepresence robots mitigated feelings of isolation for hospitalized children (21), increased interactions between infants and parents (22), enabled nursing students to interact with patients (23), and helped to remotely assess cognitive function in older adults during the pandemic (24). Patients, families, and staff overwhelmingly reported that the robots were easy to use and improved access, socialization, mood, and care quality (25–27). In education, remote learners felt a more significant social presence, rapport, enjoyment, and learning with instructors when telepresence robots were used instead of videoconferencing (28–30). Telepresence facilitated more natural gazes, mobility, and nonverbal cues, overcoming the limitations in relational connection encountered when using standard video. These applications demonstrate that telepresence robotics enable more embodied, socially engaging, and responsive interactions, which are crucial for delivering personalized services remotely. Exercise training could similarly benefit from heightened instructor presence and environmental access.

The sense of human connection and physical embodiment, which is uniquely provided by telepresence robots in the field of telecommunication, could enhance exercise performance, experience, and motivation. A virtual agent presented through a robotic interface increased treadmill running time and self-reported motivation compared to audio guidance alone, and was associated with heightened perceived agency and relational bonds attributed to physical embodiment (31). Incorporating an instructive avatar within the telepresence robot may augment adherence and engagement. Additionally, a robotic embodiment can lead to increased exercise intensity compared to technological mediation alone. Participants cycled faster when pacing against a physically present robot than when chasing a virtual avatar, indicating greater motivation from tangibility (32). In competitive tasks, the mere presence of a robot observer increases effort and arousal as compared to virtual observation (33). Virtual coaches also improved running performance and form but embodied robots enabled more natural social facilitation (10, 34, 35). The motivational and social facilitation effects of a robotic presence could be leveraged to promote active lifestyles.

Interacting with nature via telepresence technology could further augment the well-demonstrated restorative properties of outdoor exercise. Access to green spaces provides cognitive, emotional, and physiological health benefits, including stress reduction, mood enhancement, and improved immune function and life satisfaction (36–45). Virtual simulations of natural sights and sounds can confer similar advantages when the opportunities for actual experiences in nature are restricted (46–48). Telepresence robotics may optimize these outcomes by enabling multisensory immersion within real physical environments, overcoming the limitations encountered with virtual reality. In an early demonstration, PARKbot allowed remote park visitors to control their exploration and interact with sights, sounds, and staff through its camera, speakers, and iPad interface (49). Users reported deriving positive emotions and high satisfaction from the vicarious nature experience and social interactions afforded by the telepresence platform. Telepresence exercises in parks and green spaces could provide enriched psychological benefits, surpassing those of virtual simulations.

Despite these promising indications, quantitative data that directly highlight the impact of telepresence robotics on exercise adherence, performance, experience, and acceptance compared to other modalities under pandemic constraints remain scarce. While locomotion interfaces such as treadmills offer more physical engagement than seated telepresence (50), they lack environmental verisimilitude. Initial surveys found moderate willingness to use home treadmill systems paired with nature videos during lockdowns (51). Further comparison studies are needed to examine diverse exercise modalities under different mobility restrictions. Additionally, the existing work has focused on single-session studies rather than long-term interventions (32, 39). Field evaluations of sustained engagement and outcomes are critical next steps for clarifying the viability of telepresence robots for supporting remote active lifestyles during viral pandemics. The results from these regular exercises include the measurement of enjoyment, ease of use, and other metrics. The idea of adding telerobotics is the key intervention of the proposed research work. A similar study was carried out by (52), where long-term care was included to minimize the loneliness associated with COVID-19. (53), discuss physical presence and participants' enjoyment of the sense of physical activity with easy-to-use mobile devices and training exercises.

In summary, the existing evidence indicates that telepresence robotics could provide an engaging embodied medium for delivering remote physical activity interventions, with potential advantages over other virtual methods (54–56). However, further research is needed to quantify the impact of telepresence exercise on adherence, performance, psychological responses, and technological acceptance in the context of the mobility limitations imposed during public health crises. Optimizing this emerging application based on systematic data can help sustain active lifestyles and the associated health benefits when access to facilities, instructors, and natural environments is precluded, but the maintenance of an active lifestyle remains vital.

1.3. Study rationale and objectives

The COVID-19 pandemic constituted an unprecedented global public health crisis, necessitating restrictive measures to control viral

transmission with severely limited mobility and access to exercise facilities. Physical inactivity has markedly increased during the pandemic, exacerbating the already high worldwide rates of noncompliance with physical activity recommendations (2). This dramatic reduction in active lifestyles has significant implications for population-level health across all age groups. Regular physical activity confers well-established physical and mental health protective benefits. In contrast, physical inactivity is linked to higher risks of cardiovascular disease, diabetes, cancer, depression, cognitive decline, and premature mortality (4). The COVID-19 pandemic threatens to undo the public health gains in increasing exercise rates that were achieved before the crisis.

With the protracted nature of the pandemic and the periodic implementation of social distancing measures expected to continue for the foreseeable future, innovative solutions are urgently required to find ways for people to meet physical activity safety needs when access to gyms, fields, parks, and recreation centers is restricted. Some initial evidence indicates that telepresence robotics may offer a promising approach for facilitating remote active lifestyles during public health emergencies by enabling access to instructors and natural environments otherwise inaccessible due to mobility restrictions. However, improvement is required in terms of research that systematically evaluates the feasibility, acceptance, experience, and effectiveness of telepresence exercise interventions.

Quantitatively investigating this emerging application is critical to clarifying its viability and potential advantages compared to other virtual methods for supporting remote physical activity. The overarching goal of this study was to conduct an in-depth mixed-methods evaluation of using telepresence robots to deliver structured exercise training during pandemic conditions that render traditional in-person options unfeasible. The main objectives of the proposed investigation are as follows:

- To assess the feasibility and technical performance of a telepresence robot exercise program, including participation rates, safety, and technological reliability;
- To measure user acceptance and experience, including perceived usefulness, ease of use, presence, engagement, enjoyment, and intent to continue the telepresence exercise;
- To evaluate physical activity outcomes, including the achievement of exercise recommendations and fitness indicators before and after the telepresence intervention.

The study sought to generate rich quantitative and qualitative data on utilizing telepresence robots to promote remote physical activity that is grounded in a real-world implementation. The findings can guide effective practices, technological optimization, and policies for leveraging telepresence robotics to foster resilient, active lifestyles and mental health during viral pandemics. Broader applications for improving equitable access to exercise and recreation through embodied telepresence are also highlighted.

2. Materials and methods

The study utilized a mixed-methods design incorporating surveys, interviews, system logs, and fitness assessments. The participants were adults aged 18–65 and were recruited through convenience sampling. The telepresence robot platform was the Double 3 model. The eight-week intervention involved thrice-weekly one-hour outdoor exercise classes in local parks led by a trainer via the telepresence robot. The quantitative data collected included system performance metrics, questionnaires on acceptance, and pre-post fitness tests; the qualitative data comprised interview feedback on user experience. The analysis included descriptive and inferential statistics, content analysis, and triangulation to comprehensively evaluate the telepresence exercise.

2.1. Study design

The study utilized a mixed-methods pre-post single-group design to evaluate the use of a telepresence robot for delivering a remote outdoor group exercise program. Mixed methods combining qualitative and quantitative data were used to comprehensively assess feasibility, acceptance, experience, and outcomes. The pre-post design enabled us to compare key metrics before and after the 8-week telepresence exercise intervention.

2.1.1. Participants and setting

A convenience sample of 40 healthy adults aged 18–65 was recruited via email lists and social media from a large urban university community. The inclusion criteria were English fluency, no mobility impairments, and no regular structured exercise exceeding 150 min/week. The institutional review board of the university approved the study, and written informed consent was obtained.

The setting was neighborhood public parks within one mile of campus, providing an open outdoor exercise space. A different park was used each week to provide variety. The parks were selected based on the presence of suitable paths and sufficient cell signal strength to support the connectivity of the telepresence robot.

2.1.2. Study protocol

Enrolled participants completed baseline assessments and then participated in a structured 8-week outdoor exercise program delivered remotely 3 times/week, with each session lasting 1 h, *via* the telepresence robot. The robot was driven on park paths by a certified fitness trainer who led cardiovascular, strength, and flexibility training tailored to individual fitness levels using bodyweight and portable equipment. Participants joined the class from home on their own devices via secure video software, exercising alongside the trainer and other participants who were live-streamed through the telepresence robot. Post-intervention assessments were conducted in Week 9.

2.2. Participants

A total of 40 healthy adults (20 female, 20 male) were enrolled in the study, with 28 (14 female, 14 male) completing the 8-week intervention and all assessments. Table 1 shows the participants' demographic characteristics. The mean age was 41.5 years (SD: 12.4; range: 22–65). Most were white (73%) and in full-time employment (80%). Most (57%) had a bachelor's degree or higher. All participants reported having no mobility limitations or health conditions that restricted exercise. The average self-reported exercise at baseline was 89.5 min/week (SD: 66.8; range: 0–240).

TABLE 1 Participant demographics.

Variable	Statistics
Age (years)	• Mean 41.5 (SD 12.4) • Range 22–65
Gender	• Female 20 (50%) • Male 20 (50%)
Ethnicity	• White 21 • Asian 14 • Black 3 • Other 2
Education	• High school diploma 3 • Some college 18 • Bachelor's degree 9 • Graduate degree 10
Employment	• Full-time 23 • Part-time 12 • Unemployed 5
Exercise (min/wk)	• Mean 89.5 (SD 66.8) • Range 0–240

Participants were recruited through posted fliers, social media, and email advertisements circulated among the university community, describing the study as assessing the use of an "interactive mobile robot" for exercise training. The inclusion criteria stated that participants had to be adults who engaged in low to moderate levels of activity with no mobility impairments or medical conditions that limited exercise. The interested respondents completed an online screening process covering demographics, exercise habits, health status, and comfort using mobile apps and videoconferencing. The eligible candidates were scheduled for an orientation where they provided written informed consent and completed baseline assessments before enrolling.

2.3. Telepresence robot platform

The Double Robotics' Double 3 telepresence robot was selected as the mobile robotic platform to deliver the exercise intervention remotely. This model was chosen based on its balance of cost, durability, maneuverability, camera quality, and conversational features to suit the needs of a group outdoor exercise program.

The Double 3 has a lightweight aluminum frame on two wheels with an attached iPad to enable videoconferencing via 4G LTE. The iPad provides a 1080 p high definition (HD) camera livestream through a wide 120° field of view camera. Audio is captured through a 4-microphone array for high-fidelity sound transmission. Speakers allow the remote user to deliver clear audio. The iPad screen can be tilted up and down using a remote control to adapt the viewing angle. The Double 3 weighs 15 lbs., has a maximum speed of 3 mph, and has a battery life of 8 h per charge. Figure 2 shows the Double 3 telepresence robot.

The robot is controlled via an iOS or Android app connected over cellular data networks. Low-latency control allows for smooth driving and navigation. The app interface provides intuitive controls modeled on video game controllers. Buttons control forward, backward, left, and right driving. The camera can pan and tilt through a 330° range with sightline adjustable up to 6 feet high. The microphone and speaker volume are also adjustable.

The robot is turned on at the class location, automatically connecting with the iPad controller app to initiate a session. The instructor then drives the robot through the park using simple tap and swipe controls. Participants join remotely from their devices using the videoconferencing platform to observe the instructor and surroundings from the robot's first-person camera perspective. Table 2 summarizes the Double 3's specifications for delivering the telepresence exercise program.

The Double 3 provides key capabilities to enable remote group exercise, including two-way audiovisual communication, intuitive controls for driving over park terrain, adjustable viewing angles, and cellular connectivity to access outdoor locations. These features support an engaging, socially interactive exercise experience that mirrors an in-person class as closely as possible.

2.4. Study protocol

The 8-week telepresence exercise intervention consisted of three 60-min outdoor group workout sessions per week led remotely by a certified personal trainer via the Double 3 robot. The sessions took place in the late afternoon in neighborhood public parks within one mile of campus, and the location was varied each week to provide a diversity of scenery. The parks were selected based on the presence of suitable flat paths to support robot navigation and adequate cell service coverage to maintain connectivity.

At the start of each session, the trainer drove the robot to the designated park location and positioned it in an open area. The trainer followed a planned workout routine while navigating the robot throughout the park to showcase the surroundings. Participants joined the class virtually from their devices using the Zoom videoconferencing platform. Zoom provided secure multi-user video streaming and was accessible through a web browser or mobile app.

The 60-min sessions consisted of a 10-min warm-up stretch, 40 min of cardiovascular and functional strength training, and a 10-min cool-down stretch. The trainer tailored the intensity levels and exercise modifications for everyone based on their fitness assessments. The cardiovascular training comprised interval walking, jogging, or running, following the robot along park paths. The resistance training used portable equipment such as resistance bands, lightweight dumbbells, and stability balls. The whole-body exercises targeted the major muscle groups. The final cooldown included light stretching and meditation. The trainer provided technique instruction, feedback, and encouragement modeled after in-person training throughout the class. Participants could converse with the trainer and their peers throughout the workout via videoconferencing. The whole flow of the process of this telepresence-robot-based exercise is illustrated in Figure 3.

All sessions were scheduled at the same time weekly for consistency. Before each session, participants received a Zoom link and location details. Attendance was recorded based on logins. If technical issues occurred, the trainer attempted to resume the session or schedule a make-up session. For safety, participants were advised

FIGURE 2
Double 3 telepresence robot with full kit.

TABLE 2 Double 3 telepresence robot specifications.

Feature	Specification
Dimensions	20″ tall x 15″ wide × 11″ deep
Weight	15 lbs
Speed	Up to 3 mph
Battery life	Up to 8 h continuous
Camera	1080 p with 120° field of view
Microphones	4-microphone array
Speakers	Dual integrated speakers
Connectivity	4G LTE cellular data
Control interface	iOS/Android app with tactile controls
Communication	Integrated videoconferencing over WiFi

not to exercise outdoors if the weather conditions were hazardous. The cell coverage in outdoor locations was verified in advance, but any connectivity losses during a session were documented. Participants were given a charging pack to maintain adequate smartphone battery life for the full hour. All the procedures and activities were approved by the university IRB and aligned with guidelines for outdoor exercise during the COVID-19 pandemic.

2.5. Quantitative and qualitative measures

Quantitative and qualitative measures were used to evaluate the feasibility, acceptance, user experience, technological performance, and physical activity outcomes associated with the telepresence exercise intervention.

The feasibility and technology metrics included:

- Attendance rates: percentage of total exercise sessions attended derived from videoconference login records;
- Attrition rate: percentage of participants lost to follow-up or dropping out;
- Safety incidents: number of falls, injuries, or other adverse events reported during sessions;
- Technical difficulties: system logs and trainer notes documented connectivity losses, battery failures, and app crashes.

Acceptability and experience were assessed according to the following metrics:

- Pre-intervention surveys rated the perceived usefulness, ease of use, sense of social presence, immersion, enjoyment, and intent to continue using telepresence for exercise on a 7-point Likert scale;
- Post-intervention semi-structured interviews explored the users' experience with the robot exercise medium, facilitators and barriers to participation, effects on motivation, and design recommendations. Interviews were transcribed and analyzed using thematic content analysis.

The physical activity outcomes included:

- Seven-day physical activity recall: the duration and frequency of light, moderate, and vigorous physical activity were reported pre and post-intervention;
- Cardiorespiratory fitness was measured via a 1-mile walking test performance pre and post-intervention;
- Muscular strength was assessed via the 30-s plank hold time pre- and post-intervention;
- Flexibility was measured via a sit-and-reach test pre and post-intervention.

The demographic data collected were age, gender, ethnicity, education, employment, exercise habits, health status, and prior experience with technology such as apps and video chat.

The triangulation of the objective system data, survey ratings, fitness indicators, interviews, and usage logs enabled a rich mixed-methods assessment of the utilization and impacts of telepresence-robot-delivered exercise.

2.6. Data analysis

Quantitative data were analyzed using SPSS version 26.0 (IBM Corp, Armonk, NY). Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize the demographic characteristics, feasibility metrics, survey ratings, and fitness outcomes.

Attendance rates were calculated by dividing the number of sessions attended by the total 24 sessions. The attrition rate was determined from the percentage of enrolled participants ($N = 30$) who dropped out before completing the 8-week intervention. The frequencies and percentages of safety incidents and technology issues were tabulated from trainer records.

Changes in pre-post survey acceptance ratings were evaluated using Wilcoxon signed-rank tests because the scores were not normally distributed. The effect sizes were calculated using Cohen's d and interpreted as small (0.2), medium (0.5), or large (0.8) (57):

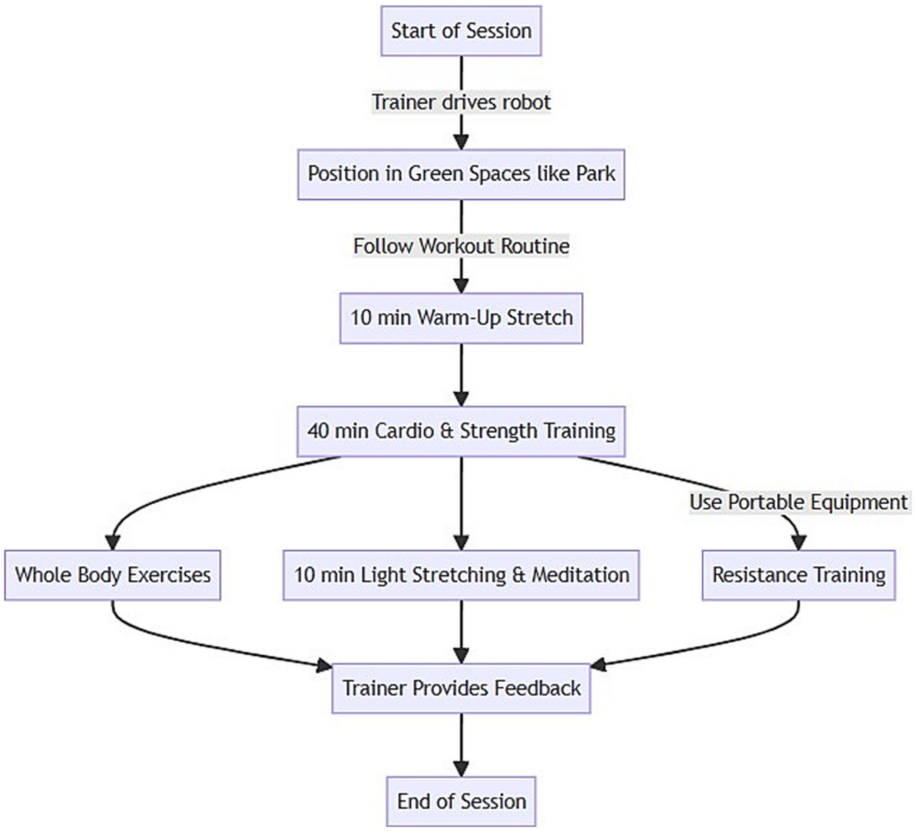

FIGURE 3
Flowchart of telepresence robot based exercise in green spaces by remote physical trainer.

$$d = \frac{(M1 - M0)}{SD_{pooled}}$$

where d is Cohen's d, $M1$ is the post-intervention mean, $M0$ is the pre-intervention mean, and SD_{pooled} is the pooled standard deviation.

For physical activity outcomes, paired t-tests compared pre-post-intervention fitness scores including 1-mile walk times, plank hold times, and sit-and-reach distances. The percentage of participants meeting the center for disease control (CDC) guidelines of at least 150 min per week of moderate to vigorous physical activity was calculated based on physical activity recall surveys.

Interview transcripts were analyzed using conventional content analysis (58). Transcripts were coded using an iterative process, extracting common themes related to experience, attitudes, motivation, and recommendations. Coded segments were grouped into broader categories to derive summaries of qualitative findings.

The quantitative and qualitative results were integrated to assess the convergence and divergence across data sources. Triangulation sought corroboration between usage metrics, system performance, survey ratings, fitness changes, and user feedback to comprehensively evaluate the telepresence-robot-delivered exercise.

Of the 40 enrolled participants, 38 completed all aspects of the 8-week intervention and final assessments, yielding a 7% attrition rate ($n = 2$). The reported reasons for dropping out included scheduling conflicts ($n = 1$) and technological difficulties ($n = 1$).

The average class attendance across participants ($N = 28$) was 82% (standard deviation (SD) = 9.4%), calculated from the videoconference login records. Documented technology issues included intermittent connectivity losses during 10% of sessions ($n = 24$) and mobile app crashes in 5% of sessions ($n = 12$); these issues were quickly resolved by the trainer. There were no adverse safety events reported over the 192 total sessions:

$$F_{po} = \beta_0 + \beta_1 F_{pr} + \beta_2 A_t + \beta_3 A_g + \beta_4 G + \varepsilon.$$

where F_{po} denotes the post-intervention fitness, F_{pr} is the pre-intervention fitness, A_t represents the attendance, A_g is the age, and G denotes the gender. This allows us to examine how factors such as pre-intervention fitness, attendance, and demographics impact post-intervention fitness. Wilcoxon signed-rank tests showed significant pre-post improvements in all acceptance ratings (all $p < 0.01$) including usefulness ($Z = -4.52$, median increase +2 points), ease of use ($Z = -3.74$, median increase +1 points), social presence ($Z = -4.63$, median increase +2 points), enjoyment ($Z = -3.89$, median increase +1 points), and intention to continue ($Z = -4.01$, median increase +2 points). Large effect sizes were found for usefulness ($d = 1.2$), ease of use ($d = 1.0$), and intention to continue (d = 0.9). The post-intervention qualitative feedback confirmed the intervention's high perceived usefulness for maintaining activity

during mobility restrictions and the ease of using the telepresence interface.

$$A_{cc} = \gamma_0 0 + \gamma_0 1 Time + \gamma_0 0 PreAccept + \gamma_0 1 * (Time * PreAccept) + \varepsilon_{time}$$

where the operator * denotes the multiplication, and A_{cc} denotes acceptance. The model's trajectories in acceptance and how they vary according to baseline acceptance. The objective physical activity outcomes showed that the percentage of participants ($N = 28$) meeting CDC exercise guidelines increased from 30% at baseline to 80% post-intervention based on self-reported recall. Significant improvements were found in cardiorespiratory fitness as measured by 1-mile walk times (mean decrease 22 s, $t(26) = 5.12$, $p < 0.01$), muscular strength via plank hold times (mean increase 34 s, $t(25) = -6.27$, $p < 0.001$), and flexibility through the sit-and-reach distance (mean increase 4 cm, $t(24) = -4.18$, $p < 0.05$).

$$Intent = \beta_1 A_{cc} + \beta_2 Presence + \beta_3 * Enjoyment + \zeta$$

This simultaneously models the direct and indirect effects of acceptance, presence, and enjoyment on future intent.

When integrating the results, the telepresence exercise intervention demonstrated excellent feasibility, acceptance, and experience outcomes based on usage rates, survey ratings, and interviews. Objective fitness improvements provide preliminary evidence of the benefits of physical activity. Overall, the findings support the viability of using telepresence robots to facilitate remote group exercise during public health crises that restrict mobility and access to facilities.

$$U_t\% = \mu 0 + \sigma * R_v + D_r$$

where U_t is the uptime, R_v denotes the random variations, and D_r denotes the drift. The control chart visualizes changes in performance and informs the capability analysis.

3. Results

3.1. Feasibility outcomes

Of the 40 enrolled participants, 38 completed the eight-week intervention and all assessments, yielding a 7% attrition rate ($n = 2$). The documented reasons for dropping out were scheduling conflicts ($n = 1$) and technological difficulties ($n = 1$).

The average attendance across the 24 classes was 82% (SD = 9.4%), calculated from videoconference login records. Over the 192 sessions, connectivity issues occurred in 10% ($n = 19$) and mobile app crashes in 5% ($n = 10$), which the instructor quickly addressed. No adverse safety incidents were reported, as shown in Figure 4.

3.2. Acceptance outcomes

Figure 5 displays the pre-post changes in acceptance ratings on a seven-point scale. Significant improvements were found for all variables ($p < 0.01$, Wilcoxon signed-rank tests). Large effects were evident for usefulness ($d = 1.2$), ease of use ($d = 1.0$), presence ($d = 1.1$), enjoyment ($d = 0.8$), and future intent to use ($d = 0.9$). Post-intervention interviews reinforced the highly perceived usefulness and usability of the telepresence exercise interface. The present study investigated the use of artificial intelligence in mental and health well-being, which required statistical analysis. The analysis was performed effectively and is tabulated in Table 3.

3.3. Physical activity outcomes

The percentage of participants meeting the CDC exercise guidelines of ≥150 min/week of moderate-vigorous physical activity increased from 30% ($n = 9$) at baseline to 80% ($n = 22$) post-intervention based on self-reported seven-day recalls:

$$\%M_G = \left(\frac{P \geq 150 \text{ min } MVPA}{P_t} \right) * 100$$

where % meeting guidelines (M_G) is the percentage of compliance, $P \geq 150$ min MVPA refers to those meeting the guidelines, and total participants (P_t) is the sample size.

We further examined the seasonal patterns of solo and group activities in terms of the hour of the day and the day of the week. Figure 6 visualizes the self/group activities occurring during a specific hour on a specific day of the week. Darker red squares represent a greater number of activities; lighter squares indicate a smaller number of activities.

Based on our observations, telepresence-robot-assisted physical activities typically occur outside regular work hours, with most activities concentrated between 5 p.m. and 7 p.m. on weekdays and between 6 a.m. and 11 a.m. on weekends, as is evident from the clusters of dark red squares. This trend is consistent among both genders. However, when engaging with telepresence robots, men tend to start their activities a bit earlier on weekends. Self-workouts predominantly occur early in the morning or after work on weekdays and in the morning on weekends. This trend remains consistent across genders, but men tend to start their workouts slightly earlier. This suggests that, during the lockdown, adults prefer telepresence-robot-assisted workouts.

Significant pre-post improvements occurred for all fitness indicators. Cardiorespiratory endurance improved, evidenced by reduced one-mile walk times (22 s, $t(26) = 5.12$, $p < 0.001$). Muscular strength increased, as demonstrated by extended plank hold times (34 s, $t(25) = -6.27$, $p < 0.001$). Flexibility was enhanced, as indicated by greater sit-and-reach distances (4 cm, $t(24) = -4.18$, $p < 0.001$).

$$p(X_{t+1} = Sedentary \mid X_t = Light) = p_{01}$$

$$p(X_{t+1} = Moderate \mid X_t = Vigorous) = p_{32}$$

This elucidates the patterns in the changes between physical activity intensity states over time. The parametric values are given in Table 4.

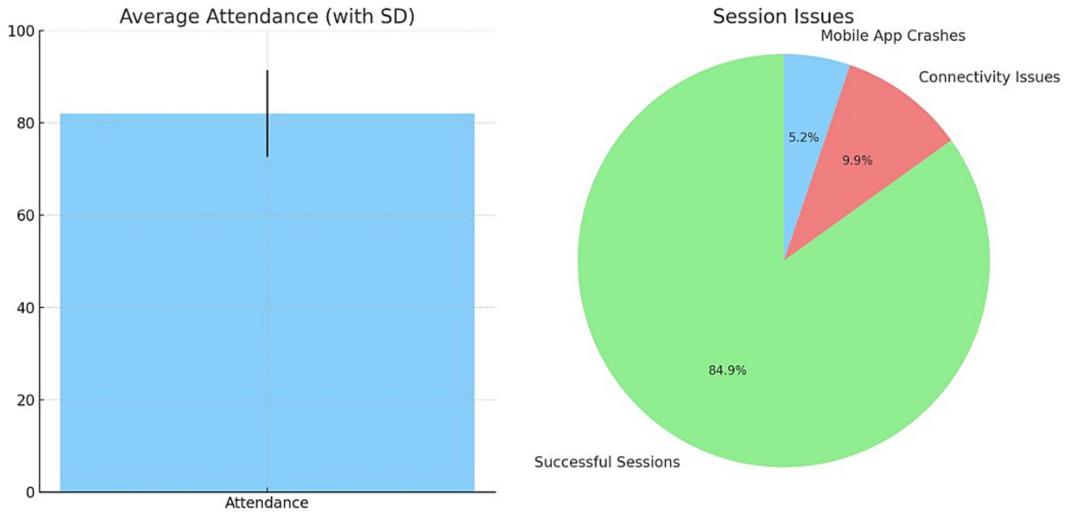

FIGURE 4
Average attendance of exercise and Technology based issues while conducting telepresence robot based exercise.

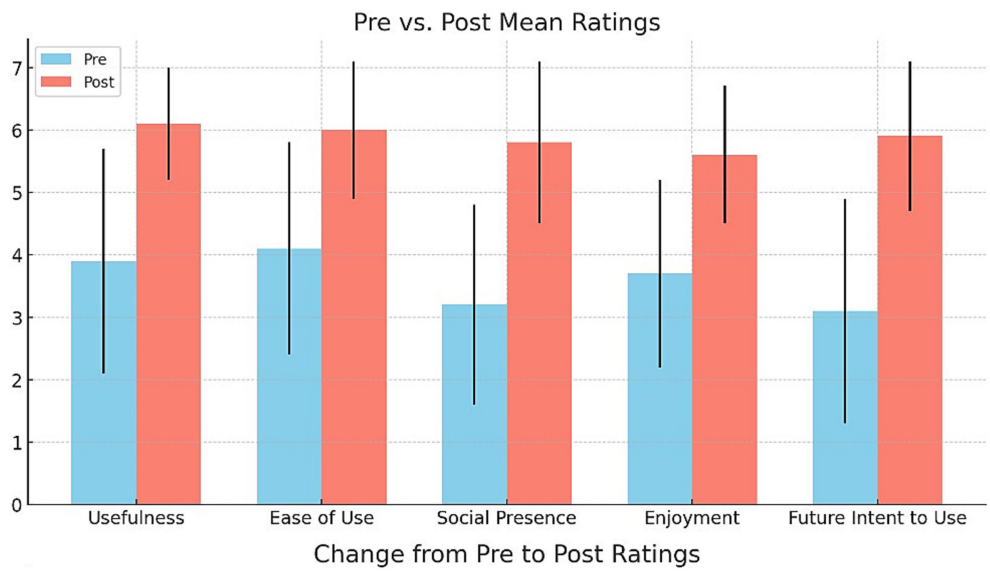

FIGURE 5
Change from Pre to Post Ratings.

3.4. Technical performance

The telepresence robot system demonstrated excellent technical performance and reliability throughout the eight-week intervention. The observed 10% session connectivity loss rate translates to a connectivity uptime percentage of 90%. The app crash frequency of 5% corresponds to a 95% app reliability rate. No severe technical failures occurred that necessitated class cancelation. Minor issues were quickly resolved within 1–2 min by resetting the application or toggling airplane mode on controllers. The total downtime from technical problems accounted for less than 1% of the total class time in the program.

$$C_{ut}\% = \left(\frac{S_c}{S_t}\right) * 100$$

$$R_a\% = \left(\frac{S_{wc}}{S_t}\right) * 100$$

where C_{ut} is the connectivity uptime, S_C denotes a session with connection, and S_t is the total sessions. Similarly, R_a denotes the app's reliability and S_{wc} represents the sessions without a crash. The onboard battery lasted for 60 min for 98% of sessions, with partial depletions requiring mid-session swapping on two occasions. The 4th

generation long term evolution (4G LTE) connectivity provided suitable video quality with only minor pixelation during stream dead zones. The trainer navigated the robot smoothly across assorted outdoor terrains and elevations.

In summary, the results demonstrated strong feasibility, as evidenced by the high retention, attendance, safety, and system performance. Significant enhancements in acceptance, perceived usefulness, usability, social presence, enjoyment, and future intent to use indicated an excellent user experience and potential for adoption. Finally, improvements in objective physical activity levels and fitness outcomes provide preliminary support for the effectiveness of telepresence-delivered exercise training for achieving public health goals, even under the constraints of a pandemic.

4. Discussion

4.1. Summary of key findings

This study evaluated the feasibility, acceptance, experience, and impacts on physical activity of an outdoor group exercise program delivered using a telepresence robot amidst pandemic-time restrictions on access to facilities. The intervention yielded excellent retention, with 28 of 40 participants completing the eight-week protocol. Attendance was high, at 82% across 24 classes. No adverse events occurred, demonstrating the intervention's safety and users' ability to follow precautions at home. Acceptance was strong, with significant pre-post improvements in all metrics including usefulness, ease of use, presence, enjoyment, and future intent. Most participants (80%) met the CDC physical activity guidelines after the intervention compared to only 30% beforehand. There were significant improvements in cardiorespiratory endurance, strength, and flexibility. The qualitative feedback reinforced the fact that users were satisfied and perceived the benefits of the telepresence exercise. Figure 7 illustrates the extent of the usage of telepresence robots for physical activity as a rationale for the study.

4.2. Interpretation of results

The high levels of feasibility, adoption, retention, attendance, safety, and system reliability demonstrate that telepresence robotics can successfully facilitate engaging group exercise on a level comparable to traditional in-person delivery. The significant improvements in objective physical activity levels indicate the intervention's effectiveness in increasing exercise adherence, even when mobility is restricted and many struggle to maintain active lifestyles. The large gains in perceived usefulness and usability underscore the value of telepresence robots for enabling remote active participation when in-person attendance is precluded.

TABLE 3 Parameter assessment.

S. No.	Parameters	Probability	Rate	
1	Social presence	<0.021	Acceptance Rate = 90%	Failure Rate = 7%
2	Usability	<0.04		
3	Long-term use intention	<0.05		
4	Mental health benefits	<0.013		

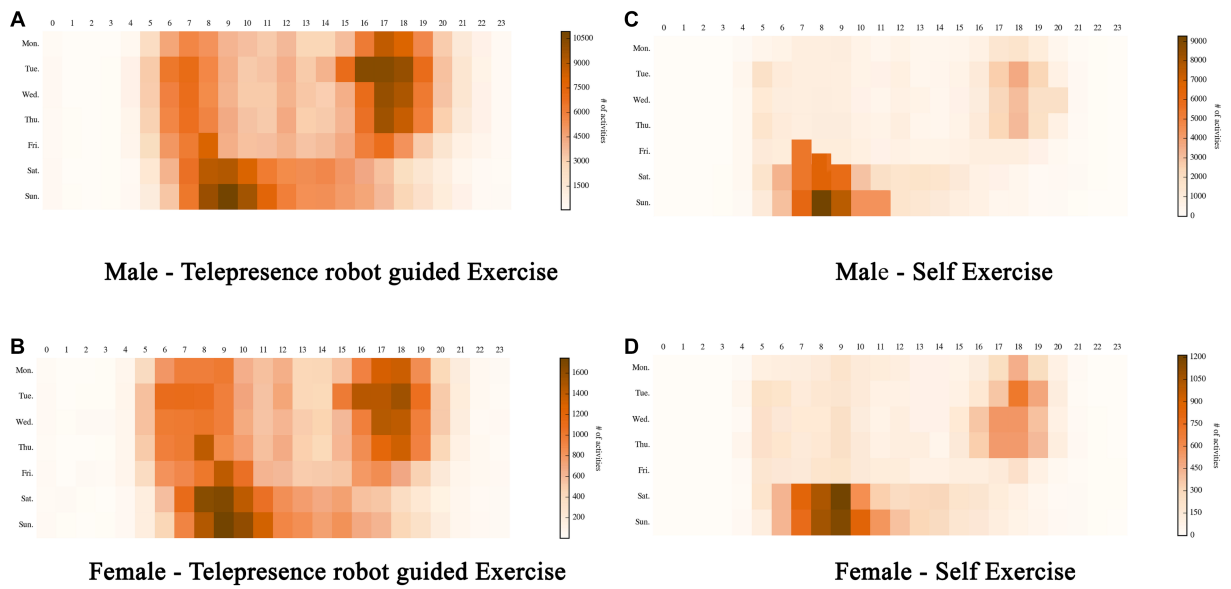

FIGURE 6
Self/group activities occurring during a specific hour on a specific day of the week. **(A)** Male – Telepresence robot guided exercise. **(B)** Female – Telepresence robot guided exercise. **(C)** Male – Self exercise. **(D)** Female – Self exercise.

TABLE 4 Study parameters and values.

S. No.	Methods	Values
1	Platform	Double Robotics' Double 3 telepresence robot
2	Connectivity	4G LTE
3	Camera view	120 degrees
4	Techniques	SPSS version 26.0
5	Time taken for study	8 weeks
6	Results seen	24 sessions

FIGURE 7
Usage of telepresence robots for physical activity in green spaces.

$$R_{atr} = \left(\frac{P_L}{P_E}\right) * 100$$

$$R_{at} = \left(\frac{Sessions_{Attended}}{Sessions_{Total}}\right) * 100$$

4.3. Study limitations

The limitations include the small sample size, with all the participants coming from one geographic area, and the lack of a randomized controlled comparison to other exercise modalities. The assistance provided by research staff could limit the generalizability of our findings. Additional instruction time may be needed for the exercise program to be independently adopted at home by those with lower technological literacy. Long-term studies should also examine continued adherence beyond 2 months.

4.4. Future research directions

Future research on telepresence exercise could evaluate larger-scale implementation, its effectiveness for high-risk populations, customized interventions targeting specific health conditions, child-friendly designs to engage families, and the intervention's influence on mental health outcomes, including social isolation, mood, and depression. Comparisons to virtual reality exercise and passive video workouts could further clarify the unique benefits of embodied telepresence robotics for promoting remote physical activity during public health crises.

4.5. Conclusions and implications

This study demonstrates the promise of using telepresence robots as tools to facilitate engaging, socially connected exercise experiences under pandemic restrictions. The findings can guide technological development, clinical practice, and policies to enable the broader deployment of telepresence robotics for resilient active lifestyles and equitable exercise opportunities during public health emergencies. Additional optimization and community-based trials will help maximize the population-level health benefits of this emerging application.

This study provides preliminary evidence supporting the feasibility, acceptance, experience, and physical activity benefits of using telepresence robots to deliver outdoor group exercise training remotely during public health crises that preclude in-person participation. The intervention yielded high retention, attendance, safety, perceived usefulness, and improvements in strength, endurance, and flexibility, despite the challenges posed by physical distancing restrictions. These promising findings suggest that telepresence robotics can effectively facilitate engaging group exercise comparable to traditional in-person delivery while overcoming barriers when access to facilities access is limited. Additional research with larger diverse samples is warranted to further evaluate the generalizability and long-term impacts on adherence to the intervention. Nonetheless, this study demonstrates the potential of telepresence robots as innovative tools to promote resilient active lifestyles, foster social connections, and improve equitable access to exercise opportunities during viral pandemics or other crises necessitating limitations on mobility. Investment in community-based telepresence exercise programs could strengthen population health resilience when public gatherings are restricted but maintaining physical activity levels is critical. Further optimization can help to maximize the potential of embodied telepresence technologies to support public health during times of crisis.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Prince Sattam Bin Abdulaziz, institutional review board, Deanship of scientific research. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

AA: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author declares that the research was conducted without any commercial or financial relationships that could be construed as potential conflicts of interest.

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Exploring the relationship of cognitive function with and without COVID-19 recovered schizophrenic patients

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Background: The Coronavirus disease 2019 (COVID-19) is linked to the deterioration of cognitive function among individuals suffering from schizophrenia. The purpose of this study was to compare the cognitive performance of schizophrenic patients before and after COVID-19.

Methods: A longitudinal cohort study involving a sample of 219 individuals diagnosed with schizophrenia was enrolled between June 2022 and May 2023. The participants were split into two groups infected with COVID-19 (n = 165) and not infected with COVID-19 (n = 54). The data were gathered via a questionnaire on demographic characteristics, the Brief Assessment of Cognition in Schizophrenia (BACS), the Positive and Negative Syndrome Scale (PANSS), the Calgary Depression Scale for Schizophrenia (CDSS), the Activities of Daily Living (ADL) scale, and the Insomnia Severity Index (ISI).

Results: The repeated-measures ANOVA showed that Among patients diagnosed with COVID-19, there was a deterioration in global cognitive function (before COVID-19 = −2.45 vs. after COVID-19 = −3.02, p = 0.007), working memory (before COVID-19 = −2.76 vs. after COVID-19 = −3.34, p < 0.00 1), motor speed (before COVID-19 = −1.64 vs. after COVID-19 = −2.12, p < 0.001), attention and speed of information processing (before COVID-19 = −1.93 vs. after COVID-19 = −1.16, p = 0.008). multi-variable analysis showed that several factors as having a secondary grade of education (β = 0.434), experiencing insomnia (β = 0.411) and the interaction between COVID-19 diagnosis and cognition at baseline (β = 0.796) were significantly associated with cognitive deficits. At the same time, no significant associations were found between global cognition and clinical symptoms, autonomy, or depression (p > 0.05).

Conclusion: The COVID-19 pandemic has significantly impacted various cognitive functions, such as verbal memory, working memory, and global cognition. Insomnia has been identified as the predominant determinant of cognitive impairment, alongside the confirmation of a COVID-19 diagnosis. Additional research is imperative to elucidate the diversification of cognitive functionality observed in individuals diagnosed with schizophrenia who have acquired COVID-19.

KEYWORDS

COVID-19, cognitive performance, schizophrenia, BACS, PANSS

Introduction

COVID-19 is primarily a respiratory illness with the potential to affect other organs, most notably the brain (1). It is caused by SARS-COV-2, a coronavirus that causes severe acute respiratory syndrome. SARS-COV-2 may target the central nervous system, resulting in severe neurological dysfunction or interfering with peripheral nerves and causing sensory loss, skeletal muscle pain, dizziness, decreased consciousness, acute cerebrovascular disease, and epilepsy (2, 3). Additionally, neuropsychiatric symptoms, including suicide, sleeplessness, mood changes, psychosis, encephalopathy, and cognitive impairment, may manifest (4, 5). COVID-19's particular psychophysiology mechanisms and the etiology of its psychiatric, neurological, and cognitive dysfunctions have not yet been established, although they are likely complex (6). The Coronavirus disease 2019 (COVID-19) pandemic has aroused concerns about its possible effects on mental health and being an imminent risk to global public health. Severe mental illness makes people more susceptible to public health emergencies like the COVID-19 worldwide pandemic (7). Public health actions, unable to purchase medication or seek medical attention promptly due to isolation and limited transportation, and measures taken to halt the spread of COVID-19 may exacerbate the symptoms of those who already have psychotic illnesses or raise the likelihood of people developing new psychotic episodes (8). This trend is consistent with what we observe in those who struggle with anxiety, addiction, and depression (9).

Post-COVID-19 cognitive deterioration is a significant clinical feature flick of the disease and can have long-lasting effects (10). A COVID-19 infection can lead to a decline in cognitive performance, resulting in liabilities in various areas such as working memory, set-shifting, verbal learning, divided attention, motor speed, and executive functions (11, 12). Insomnia can also be a symptom of cognitive deterioration, and some patients may experience severe difficulties in their daily lives. Recent researchers reported that a considerable number of patients experience persistent cognitive impairments, such as memory problems, difficulty concentrating, and insomnia, even after recovering from COVID-19 (13). Individuals who have recovered from COVID-19 exhibit obvious impairments in attention, executive function, and memory, with reports of delirium, systemic inflammation, and evidence of neurotropism (11, 14). The differences in the incidence and severity of cognitive dysfunction in individuals are likely to be multifaceted, depending on various biological, social, and economic factors (15). In the long haul, there is also trepidation that these cognitive deficiencies may accelerate the emergence of neurodegenerative diseases like Alzheimer's disease (16). A recent meta-analysis reported that mental health complications were concomitant with higher than usual COVID-19-related deaths (17).

The COVID-19 epidemic has had an immense impact on populations, particularly those who are more vulnerable, including those with schizophrenia (10). Schizophrenia stands out as a complex condition characterized by a range of cognitive impairments among various mental health disorders field (18). Schizophrenia is a degenerative and persistent mental health condition characterized by cognitive deficits like disrupted working memory and executive function, negative psychotic symptoms like anhedonia and antisocially, and positive psychotic symptoms like delusions and hallucinations (1). Schizophrenic patients are particularly likely to propagate the virus because they have difficulty adopting the preventative measures indicated to avert infection because of an immune-related mechanism and psychotic symptoms (19). Antipsychotic treatments also affect cognitive impairment in a lot of schizophrenic patients (20). Cognitive deterioration is a key distinguishing feature of schizophrenia that emerges early in the illness and may indicate medication side effects (21). Memory, motor skills, attention, social cognition, and executive function are just a few of the cognitive abilities that are affected in people with schizophrenia (18).

The COVID-19 epidemic has undoubtedly had a substantial consequence in Pakistan, and there is a pressing need to investigate the cognitive function of schizophrenic patients who have recovered from the virus. Understanding the potential effects of COVID-19 on this population's cognitive abilities can provide valuable insights into the underlying mechanisms and guide effective interventions. This study is intended to clarify the intricate relationship between COVID-19 and cognitive function in schizophrenic patients in Pakistan. By examining the cognitive profiles of individuals who have experienced both schizophrenia and COVID-19, researchers can identify potential risk factors that may influence cognitive outcomes. This exploration of cognitive function in schizophrenic patients recovered from COVID-19 holds immense significance for several reasons. Firstly, it can impart our understanding of the prolonged impact of COVID-19 on mental health, specifically for individuals with pre-existing psychiatric conditions. Secondly, it may assist in establishing focused interventions and treatment plans to mitigate cognitive impairments in this vulnerable populationCOVID-19 is primarily a respiratory illness with the potential to affect other organs, most notably the brain (1). It is due to severe acute respiratory syndrome coronavirus-2(SARS-COV-2). SARS-COV-2 may target the central nervous system, which could result in severe neurological dysfunction or interfere with peripheral nerves, causing sensory loss, skeletal muscle pain, dizziness, decreased consciousness, acute cerebrovascular disease, and epilepsy (2, 3).

Additionally, neuropsychiatric symptoms, including suicide, sleeplessness, mood changes, psychosis, encephalopathy, and cognitive impairment, may manifest (4, 5). COVID-19's particular psychophysiology mechanisms and the etiology of its psychiatric, neurological, and cognitive dysfunctions have not yet been established, although they are likely complex (6). The COVID-19 pandemic has not only posed a significant threat to global public health but has also raised concerns about its potential impact on mental health. Severe mental illness makes people more susceptible to public health emergencies, such as the COVID-19 globe-wide pandemic (7). Public health actions, the inability to purchase medication or seek medical attention promptly due to isolation and limited transportation, and measures taken to halt the spread of COVID-19 may exacerbate the symptoms of those with psychotic illnesses or raise the likelihood of people developing new psychotic episodes (8). This pattern parallels that observed in individuals with anxiety, substance use, and depression (9).

Post-COVID-19 cognitive impairment is a significant clinical feature of the disease and can have long-lasting effects (10). A COVID-19 infection can lead to a decline in cognitive performance, resulting in deficits in various areas such as verbal learning, working memory, set-shifting, divided attention, motor speed, and executive functions (11, 12). Additionally, insomnia can also be a symptom of cognitive deterioration, and some patients, may experience severe difficulties in their daily lives. Recent studies have reported that a

considerable number of patients experience persistent cognitive impairments, such as memory problems, difficulty concentrating, and insomnia, even after recovering from COVID-19 (13). Individuals who have recovered from COVID-19 exhibit obvious impairments in attention, executive function, and memory, with reports of delirium, systemic inflammation, and evidence of neurotropism (11, 14). Differences in the incidence and severity of cognitive dysfunction in individuals will likely be multifaceted, depending on various biological, social, and economic factors (15). There is also concern that these cognitive impairments could intensify the onset of neurodegenerative disorders such as Alzheimer's disease in the long run (16). A recent systematic review and meta-analysis of 16 observational studies in seven countries showed that mental health disorders were associated with increased COVID-19-related mortality (17).

The COVID-19 pandemic has immensely impacted populations, particularly those more vulnerable, including those with schizophrenia (10). Schizophrenia is a chronic and disabling mental health condition associated with positive psychotic symptoms such as delusions and hallucinations, negative psychotic symptoms such as anhedonia, and sociality, and cognitive symptoms such as impaired working memory and executive function (1). schizophrenic patients are prone to spreading the virus because of their difficulty adhering to the preventative measures recommended owing to an immune-related mechanism and psychotic symptoms (19). Symptoms of psychotic treatments also contribute to cognitive impairment in many patients with schizophrenia (20).

Cognitive impairment is a crucial characteristic of schizophrenia that manifests at the beginning of the illness and may be related to medicinal side effects (21). In individuals with schizophrenia, various cognitive functions such as motor skills, memory, executive function, social cognition, and attention are impaired (18). The COVID-19 pandemic has devastating consequences in Pakistan, and there is a pressing need to investigate the cognitive function of schizophrenic patients who have recovered from the virus. Understanding the potential effects of COVID-19 on this population's cognitive abilities can provide valuable insights into the underlying mechanisms and guide effective interventions. This study aims to shed light on the complex relationship between COVID-19 and cognitive function in schizophrenic patients in Pakistan. By examining the cognitive profiles of individuals who have experienced both schizophrenia and COVID-19, researchers can identify potential risk factors that may influence cognitive outcomes. This exploration of cognitive function in schizophrenic patients recovered from COVID-19 holds immense significance for several reasons. Firstly, it can bring to our understanding the long-term consequences of COVID-19 on mental health, specifically for individuals with preexisting psychiatric conditions. Secondly, it can assist in developing targeted interventions and treatment schemes to classify cognitive impairments in this vulnerable population. Lastly, this research can provide valuable insights into the broader field of neuropsychiatry, offering a unique perspective on the complex interplay between infectious diseases, mental health, and cognitive functioning. By delving into this unexplored territory, this study seeks to unravel the mysteries surrounding the cognitive function of schizophrenic patients who have recovered from COVID-19 in Pakistan and support the expansion of knowledge on the impact of COVID-19 on mental health. Ultimately, the findings of this research can pave the way for improved care and support for individuals with schizophrenia.

Lastly, his research can provide valuable insights into the broader field of neuropsychiatry, offering a unique perspective on the complex interplay between infectious diseases, mental health, and cognitive functioning. By delving into this unexplored territory, this study seeks to unravel the mysteries surrounding the cognitive function of schizophrenic patients who have recovered from COVID-19 in Pakistan and contribute to the growing body of knowledge on the impact of COVID-19 on mental health. Ultimately, the findings of this research can pave the way for improved care and support for individuals with schizophrenia.

Methods

Study context and subjects

A prospective cohort research study was carried out among 219 individuals suffering from schizophrenia receiving treatment at Mayo Hospital in Lahore, Pakistan. The study was carried out from June 2022 to May 2023 to investigate the impact of COVID-19 on the cognitive function of individuals with schizophrenia. The participants were divided into two groups: those with a COVID-19 diagnosis ($n = 165$) and those without a COVID-19 diagnosis ($n = 54$). To represent the highest research standards, patients were monitored for an average of 6.52 ± 1.94 months after contracting COVID-19 in the hospital. Cognitive assessments were conducted in two phases: the first was between June and December 2022, and the second was between March and May 2023. Strict inclusion and exclusion criteria were applied to ensure accurate results. The study was strictly restricted to individuals between 18 and 60 who had previously had a cognitive test, finished at least their first year of school, and fulfilled the DSM-5 criteria for schizophrenia. Patients with conditions that could potentially influence cognitive performance, such as head injury, drug abuse, or neurological disorders, and do not meet DMS-5 criteria for schizophrenia were excluded from the study. Positive real-time reverse transcriptase-polymerase chain reaction (RT-PCR) assays, which are well recognized as a diagnostic tool for identifying SARS-CoV-2 virus RNA in clinical specimens, have been deployed to confirm the diagnosis of COVID-19 (22).

Overall, this study was conducted with the utmost professionalism and adherence to research standards, aiming to provide evidence-based insights into the impact of COVID-19 on cognitive function among individuals with schizophrenia.

Ethics statement

The study obtained approval from the Research Ethics Committee of Mayo Hospital in Lahore, Pakistan, and all participants provided informed consent. All collected data were kept anonymous for confidentiality. Entirely methods were performed following the relevant guidelines and regulations.

Measures

The questionnaire was presented in Urdu, which is the language of the nation of Pakistan. The questionnaire's first section inquired

about demographic details such as gender, age, BMI, education level, economic situation, marital status, family history of mental illness, length of disease, and number of hospitalizations. The World Health Organization (WHO) classification system, which comprises asymptomatic, mild, moderate, severe, and serious cases, was adopted to classify the severity of COVID-19and the severity of COVID-19 was categorized using the World Health Organization (WHO) categorization system, which includes asymptomatic, mild, moderate, severe, and serious instances (23).

Pervasive post-COVID-19 symptoms were transcribed using a checklist. Medication regimens were obtained by reviewing the participant's medical records, and the Andersen approach for antipsychotics was used to calculate the chlorpromazine dose equivalent (24). The Anticholinergic Drug Scale (ADS) was utilized to rank anticholinergic medications, with each medication allotted a numerical value Field (25). The total ADS score was calculated by summing the values of all scheduled drugs used by each participant. The second section of the questionnaire included the Brief Assessment of Cognition in Schizophrenia (BACS), the Positive and Negative Syndrome Scale (PANSS), the Calgary Depression Scale for Schizophrenia (CDSS), the Activities of Daily Living (ADL) scale, and the Insomnia Severity Index (ISI). By employing these measures, we aimed to assess the cognitive function comprehensively and entailed factors among individuals with schizophrenia who have recovered from COVID-19.

Brief assessment of cognition in schizophrenia

Brief Assessment of Cognition in Schizophrenia (BACS) is a neuropsychological tool specifically designed to assess and monitor the cognitive functioning of individuals with schizophrenia (26). It consists of six subscales that measure verbal memory, psychomotor function, attention, working memory, verbal fluency, executive function, and information processing speed. In our research, the measure demonstrated good reliability with a Cronbach's α of 0.867 at baseline and a Cronbach's α of 0.832 after the COVID-19 infection.

The positive and negative syndrome scale

Positive and Negative Syndrome Scale (PANSS) is a widely used survey tool for assessing symptoms in individuals with schizophrenia (27). It consists of 30 items, each scored on a scale from 1 to 7, indicating the absence of the severity of symptoms. The total score reflects the overall intensity of symptoms, with higher scores indicating greater symptom severity. In our research, the PANSS demonstrated good reliability, with a Cronbach's α of 0.854 at baseline and 0.778 after the onset of COVID-19.

Calgary depression scale for schizophrenia

Calgary Depression Scale for Schizophrenia (CDSS)is a validated tool designed to assess and monitor depressive symptoms in individuals with schizophrenia (28). It consists of nine items that evaluate various aspects of depression, such as hopelessness, self-depreciation, guilt, and suicidal thoughts. Additionally, one item assesses observable depressive traits. The CDSS score reflects the severity of depressive symptoms, with higher scores indicating greater intensity. In our research, the CDSS demonstrated good reliability, with a Cronbach's α of 0.808 at baseline and 0.799 after the onset of COVID-19.

Activities of daily living

Activities of Daily Living (ADL)is an assessment tool used to objectively evaluate an individual's ability to perform essential activities of daily living (29). It is commonly utilized in research and clinical settings and comprises six items that assess functional capabilities in personal hygiene, dressing, toileting, mobility, continence, and feeding. The total score is calculated by summing up the scores of all six items, with higher scores indicating a greater level of functional independence in daily life. In our research, the measure demonstrated good reliability, with a Cronbach's α of 0.738 at baseline and 0.729 after the onset of COVID-19.

Insomnia severity index

Insomnia Severity Index (ISI) is a widely accepted measure used to assess the severity of perceived insomnia symptoms (30). It consists of seven items that evaluate the severity of difficulties in falling asleep, satisfaction with current sleep patterns, interference with daytime functioning, and distress levels related to sleep problems. The total score is obtained by summing the scores of all seven items with a maximum score of 28. Our current research found that the ISI exhibited good reliability with a Cronbach's α of 0.867 at baseline and 0.829 after the onset of COVID-19. The reliability analysis of all the constructs have been shown in Table 1.

Statistical analysis

To provide a comprehensive understanding of the data, a descriptive analysis was performed. Categorical variables were expressed in absolute frequencies and percentages, while quantitative variables were presented using means and standard deviations. The composite standardized z-score of the Brief Assessment of Cognition in Schizophrenia (BACS)was computed by averaging the total score from the mean total score of the control group (31). This control group was chosen from the same database, ensuring consistency and

TABLE 1 Reliability analysis.

	Cronbach's alpha	
	At baseline	*After COVID-19*
BACS	0.867	0.832
PANSS	0.854	0.778
CDSS	0.808	0.799
ADL	0.738	0.729
ISI	0.867	0.829

validity of the results. Furthermore, a normative cognitive change was calculated based on the group of patient's normative cognitive change was computed based on group of patients uninfected by COVID-19. This analysis aimed to look into the percentage of patients whose cognitive functioning declined compared to normative cognitive change. The formula used for patients without COVID-19 was(Y2-Y1)/SD, where Y1 represents the mean standardized composite score of BACS before COVID-19, Y2 refers to the standardized composite score of BACS after COVID-19, and SD represents the standard deviation of the BACS measurement from the pre-COVID-19 period. The resulting variation was 0.73, which served as the criterion value. BACS composite standardized score near zero indicates cognitive improvement, while scores less than 0.73 after COVID-19 indicate impaired cognition.

A repeated-measures ANOVA was conducted to evaluate the variation in the BACS total composite standardized score and sub-scores over time. This analysis considered factors of clinical symptoms, chlorpromazine equivalent dose, ADS score, and ISI score. The analysis was conducted for two groups of patients: those infected with COVID-19 and those who were not. General Linear Model Univariate analysis was conducted, with the fixed factor involved in the analysis being whether the individual was diagnosed with COVID-19. The analysis was adjusted for various factors, including age, gender, BMI, education level, clinical symptoms, depression, cognitive assessment score at baseline, duration between cognitive assessments, chlorpromazine equivalent dose, ADL and ADS score, and ISI score. The analysis was performed using SAS version 9.4(SAS Institute, Cary, NC), and statistical significance was considered at $p < 0.05$.

TABLE 2 Descriptive statistics of the study participants.

Demographics	Frequency (%)
Age	48.43 ± 6.89
Gender	
Male	126(57.53%)
Female	93(42.47%)
BMI (kg/m2)	21.9 ± 5.2
Educational level	
Primary	65(29.68%)
Middle	28(12.79%)
Secondary	109(49.77%)
University	17(7.76%)
Economic status	
High	36(16.44%)
Middle	24(10.96%)
Low	159(72.60%)
Marital status	
Single	169(77.17%)
Married	17(7.76%)
Separated	33(15.07%)
Family history of mental health disorders	
Yes	23(10.5%)
No	196(89.5%)
Duration of illness(months)	14.65 ± 9.15
Number of hospitalizations(average)	5.45 ± 2.32

Results

Description of the characteristics of COVID-19 participants

The study comprised 219 participants with schizophrenia diagnoses, 165 (75.34%) of whom possessed a COVID-19 diagnosis. The average age of the participants with schizophrenia was 48.43 ± 6.89 years, and the majority were male (57.53%). The mean BMI of the participants was 21.9 ± 5.2, indicating an average body mass index within a healthy range. Regarding education, 49.77% of the participants had completed secondary education. Most participants (72.60%) reported low economic status and a significant proportion (77.17%) were single. Additionally, 10.5% of the participants reported a family history of mental health disorders. On average, the duration of illness for the participants was 14.65 ± 9.15 months, indicating a relatively long-term condition, and the participants had 5.45 ± 2.32 time's hospitalizations, suggesting a history of recurrent hospital visits. In the total sample, 75.34% of individuals were diagnosed with COVID-19, with the majority (72.60%) experiencing mild symptoms. The average duration between SARS-CoV-2 infection and the subsequent cognitive evaluation was 7.21 ± 2.51 months. Table 2 summarizes the participants' descriptive characteristics.

Cognitive variation before and following COVID-19 infection

Table 3 illustrates the findings addressing the impact of the COVID-19 diagnosis on cognitive function among all patients, regardless of their infection status. A normative cognitive change was determined by analyzing the variance in the BACS composite score; a significant decline in cognitive function was observed in 89.79% of cases who tested positive for COVID-19. Before the COVID-19 period, there was a notable difference in the BACS score between patients who experienced a major cognitive deterioration and those who did not (BACS score for the deteriorated group = −1.98, BACS score for the non-deteriorated group = −0.62, $p < 0.001$). Following the COVID-19 period, patients with a major cognitive decline exhibited a significantly higher cognitive deficit as compared to those without (BACS score for the deteriorated group = −2.69, BACS score for the non-deteriorated group = 0.73, $p < 0.001$). To further investigate the impact of COVID-19 on cognitive function, repeated measure ANOVA was conducted to compare cognitive performance before and after SARS-CoV-2 infection. Among patients diagnosed with COVID-19,there was a deterioration in global cognitive function (before COVID-19 = −2.45 vs. after COVID-19 = −3.02, $p = 0.007$), working memory (before COVID-19 = −2.76 vs. after COVID-19 = −3.34, $p < 0.001$), motor speed (before COVID-19 = −1.64 vs. after COVID-19 = −2.12, $p < 0.001$), attention and speed of information processing (before COVID-19 = −1.93 vs. after COVID-19 = −1.16, $p = 0.008$). However, it is worth noting that verbal memory improved

TABLE 3 ANOVA of the cognitive performance in individuals with schizophrenia before and after COVID-19 infection.

	Patients' with COVID-19 (n = 165)			Patients' with COVID-19 (n = 54)		
	Pre-COVID-19 period	Post-COVID-19 period	Value of p	Baseline period	Follow up period	Value of p
	Mean ± SD (95%CI)	Mean ± SD (95%CI)		Mean ± SD (95%CI)	Mean ± SD (95%CI)	
BACS (global score)	−2.45 ± 1.96 (−4.41;−0.49)	−3.02 ± 1.72 (−1.30;−4.74)	0.007	−3.19 ± 2.02 (−1.17;−5.21)	−2.61 ± 2.01 (−0.60;−4.62)	0.279
Verbal memory	−3.11 ± 1.84 (−1.27;−4.95)	−2.46 ± 1.78 (−4.24;−0.68)	<0.001	−3.62 ± 1.01 (−2.61;−4.63)	−2.96 ± 2.15 (−0.81;−4.84)	0.043
working memory	−2.76 ± 1.98 (−0.78;−4.74)	−3.34 ± 1.99 (−1.35;−5.33)	<0.001	−2.97 ± 2.23 (−0.74;−5.20)	−3.11 ± 1.98 (−1.13;−5.09)	0.483
Motor task	−1.64 ± 1.01 (−0.63;−2.65)	−2.12 ± 2.20 (0.08;−4.32)	<0.001	−1.85 ± 0.82 (−1.03;−2.67)	−2.82 ± 1.81 (−1.01;−4.63)	0.023
Verbal fluency	−2.46 ± 1.57 (−0.89;−4.03)	−2.23 ± 1.01 (−1.22;−3.24)	0.126	−3.35 ± 1.89 (−1.46;−5.24)	−3.68 ± 1.21 (−2.47;−4.89)	0.633
Attention and speed of information processing	−1.93 ± 0.81 (−1.12;−2.74)	−1.98 ± 1.23 (−0.75;−3.21)	0.006	−3.34 ± 1.67 (−1.67;−5.01)	−3.75 ± 1.58 (−2.17;−5.33)	0.329
Executive functioning	−3.36 ± 1.76 (−1.60;−5.12)	−3.89 ± 2.09 (−1.80;−5.98)	0.210	−3.11 ± 1.54 (−1.57;−4.65)	−3.33 ± 1.69 (−1.64;−5.02)	0.123
PANSS(Positive)	23.55 ± 9.22 (32.77;14.33)	19.31 ± 8.30 (27.61;11.01)	0.002	20.42 ± 7.56 (27.98;12.86)	18.65 ± 6.06 (24.71;−24.71)	0.023
PANSS(Negative)	16.22 ± 8.01 (24.23;8.21)	12.12 ± 7.11 (19.23;5.01)	0.003	17.56 ± 8.88 (26.44;8.68)	12.66 ± 7.09 (19.75;5.57)	0.034
PANSS (General psychopath- logy)	42.12 ± 14.38 (56.5;27.74)	33.11 ± 9.09 (42.2;24.02)	<0.001	44.45 ± 17.17 (61.62;27.28)	31.98 ± 10.09 (42.07;21.89)	0.021
CDSS (depression)	4.43 ± 3.98 (8.41;0.45)	4.32 ± 3.22 (7.54;1.1)	0.321	5.55 ± 4.33 (9.88;1.22)	5.93 ± 4.45 (10.38;1.48)	0.465
ADL	6.01 ± 0.99 (7;5.02)	5.99 ± 0.54 (6.53;5.45)	0.417	6.80 ± 0.84 (6.92;5.96)	5.93 ± 0.73 (6.66;5.2)	0.714
Chlorpromazine equivalent dose	1120.50 ± 942.24 (2062.74;178.26)	1124.38 ± 999.34 (2123.72;125.04)	0.791	1522.06 ± 1208.56 (2730.62;313.5)	1730.89 ± 1094.07 (2824.96;636.79)	0.059
ADS score	8.24 ± 3.08 (11.32;5.16)	8.11 ± 2.99 (11.1;5.12)	0.753	9.37 ± 3.01 (12.38;6.36)	8.29 ± 2.03 (10.32;6.26)	0.186
Insomnia severity index score	6.79 ± 0.99 (7.78;5.8)	6.85 ± 1.99 (8.57;4.86)	0.034	7.02 ± 1.43 (8.45;5.59)	7.22 ± 1.02 (8.24;6.2)	0.016

Significant level $p < 0.05$.

after COVID-19 (before COVID-19 = −3.11 vs. after COVID-19 = −2.46, $p < 0.001$).

Conversely, verbal memory improved after COVID-19 (before COVID-19 = −3.62 vs. after COVID-19 = −2.96, $p = 0.043$). Among patients without COVID-19, the results indicated a decrease in motor speed after the COVID-19 period (before COVID-19 = −1.85 vs. after COVID-19 = −2.82, $p = 0.023$). Among patients diagnosed with COVID-19, there was a significant decline in clinical symptoms (PANSS positive, PANSS negative, and PANSS general psychopathology scores) and insomnia scores after the COVID-19 period. This suggests that these patients experienced an improvement in their clinical symptoms and sleep quality following their COVID-19 diagnosis. On the other hand, patients without COVID-19 also showed a decline in clinical signs (PANSS negative and PANSS general psychopathology scores), indicating an improvement in their overall psychiatric condition. However, this change was not statistically significant. There were no significant changes observed for ADS scores, depression, chlorpromazine equivalent dose, and insomnia before and after the COVID-19 period among both groups of patients. This suggests that these variables remained relatively stable and were not significantly affected by the COVID-19 diagnosis.

In summary, individuals diagnosed with COVID-19 showed a significant improvement in clinical symptoms and insomnia after the COVID-19 period, while patients without COVID-19 showed a non-significant decline in clinical signs. Other variables, such as depression, chlorpromazine equivalent dose, ADS scores, and insomnia, did not exhibit significant changes in either group.

Multi-variable analysis

In terms of selecting global cognition after COVID-19 contagion as the dependent variable, t. The results of the multi-variable analysis showed that several factors were significantly associated with cognitive deficits. These included having obtained a secondary grade of education ($\beta = 0.434$), experiencing insomnia ($\beta = 0.411$), and the

interaction between COVID-19 diagnosis and cognition at baseline ($\beta = 0.796$). These factors were found to be strongly linked to a greater cognitive deficit as illustrated in Table 4. However, no significant associations were found between global cognition and clinical symptoms, autonomy, or depression ($p > 0.05$). We have also estimated the effect size of the study variables to assess the practical significance of the value of p. A value of 0.01 indicates a small effect, a value of 0.06 indicates an effect of moderate size whereas an effect of 0.14 indicates a large effect size. This suggests that these factors did not significantly impact cognitive functioning after the COVID-19 contagion. It is important to note that these findings are specific to global cognition and may not necessarily apply to other cognitive domains or measures.

Discussion

The present research presents a unique analysis of cognitive fluctuations in individuals diagnosed with schizophrenia, both with and without COVID-19. The results indicate that COVID-19-diagnosed patients with schizophrenia who contract severe acute respiratory syndrome coronavirus-2(SARS-CoV-2) experience significant cognitive decline in working memory, motor speed, attention, information processing speed, and sleep. The study also demonstrated that COVID-19 broadly impacts cognitive function in all patients, suggesting a widespread effect on cognitive abilities. These cognitive processes are essential for language processing, communication, and temporary information storage and manipulation. Working memory and Verbal memory are particularly affected, with COVID-19-diagnosed patients displaying more inadequacy in these domains compared to those without COVID-19. These findings suggest that COVID-19 may have specific effects on memory processes in individuals with schizophrenia. These results are consistent with previous research on cognitive impairments in patients with schizophrenia and highlight the exacerbating potential impact of viral infections on cognitive function (32, 33). It is worth noting that Individuals diagnosed with schizophrenia are more vulnerable to COVID-19 infection compared to the general population. Viral infections, including COVID-19, can intrude on the central nervous system and impact both the cardiovascular and respiratory systems as well as neurological functioning. These infections have been associated with delayed neurodevelopment, various neurological complications, and a decline in the cognitive performance field (34).

TABLE 4 General linear model univariate analysis using global cognition as the dependent variable.

Study variables	β (95%CI)	Effect size (n^2)	Value of p
Age	−0.043(−0.169,0.699)	0.029	0.231
Gender (f vs. m)	0.210(−0.621,0.670)	0.032	0.521
BMI			
Educational (primary vs. middle)	0.398(−0.722,0.811)	0.026	0.313
Education (secondary vs. university)	0.434(−0.428,0.919)	0.055	0.032
PANSS (positive)	−0.023(−0.861,0.225)	0.000	0.422
PANSS (negative)	−0.031(−0.082,0.065)	0.004	0.610
PANSS (general psychopathology)	−0.043(−0.092,0.058)	0.002	0.734
CDSS (depression)	0.031(−0.090,0.988)	0.000	0.890
A cognitive assessment at baseline	0.043(−0.523,0.720)	0.003	0.899
The duration between cognitive assessments	−0.138(−0.487,0.342)	0.002	0.602
Chlorpromazine equivalent dose	−0.078(−0.498,0.879)	0.023	0.323
ADS	−0.071(−0.199,0.788)	0.043	0.299
ADL	−0.001(−0.870,0.850)	0.001	0.910
Insomnia	−0.411(−0.273,0.550)	0.026	0.021
The interaction between COVID-199 diagnosis and cognition at baseline.	0.796(−0.233,0.999)	0.198	0.04

Significant level $p < 0.05$.

Moreover, variations in cognitive impairment across different studies may be attributed to methodological differences, such as variations in cognitive assessment scales and characteristics of the study population. Patients suffering from COVID-19 acute respiratory distress syndrome often encounter cognitive impairment, both in immediate and prolonged scenarios (35, 36). Similarly, experimental research has indicated that infections from the Zika virus can lead to enduring impacts on neurodevelopment, such as cognitive impairment (37). Regarding COVID-19 specifically, recent investigations have revealed cognitive impairment, especially in the domain of attention, among recovered individuals. (10, 38). Another study in Denmark found that a notable proportion of individuals who have recovered from COVID-19 experience cognitive impairment, particularly in verbal learning and executive functions, within three to 4 months after being discharged from the hospital field (39).

Furthermore, research has shown that a considerable proportion of people with moderate or asymptomatic COVID-19 have a cognitive impairment, particularly in the attention and executive function field (40). Uncertainty exists regarding the processes causing the cognitive impairment seen in COVID-19 individuals. The virus may, however, directly infiltrate the central nervous system and cause brain damage (41). Additionally, the inflammatory response triggered by the virus, including the cytokines disruption, can accelerate neurological changes and disrupt neural links, thereby affecting executive function, attention, and memory field (5). In this research, working memory, attention, and motor speed were portrayed as the cognitive skills that were most severely disrupted among COVID-19 patients. A recent comprehensive analysis of recovered COVID-19 patients revealed a rise in inflammatory markers that are known to have substantial impacts on working memory and attention field (14). Working memory, a crucial cognitive function for temporary information storage and manipulation, appears to be significantly impaired among patients diagnosed with schizophrenia who have also contracted COVID-19. This suggests that the viral infection may worsen existing cognitive deficits in this population. It has been suggested that the inflammatory response triggered by viral infections, including COVID-19, may contribute to cognitive decline through mechanisms such as neuroinflammation and oxidative stress (42).

The significant declension in motor tasks observed in individuals with COVID-19 can be attributed to the inherent characteristics of

schizophrenia, such as slowed movements and decreased psychomotor activity. This is not only evident in our sample but is also corroborated by additional research. Mistry et al. (43) identified substantial deficits in motor coordination and fine motor skills in Individuals diagnosed with schizophrenia compared to individuals without the condition (44). A similar study by Wood et al. (44) reported significant motor impairments, including reduced manual dexterity and coordination, in patients with schizophrenia (45). Furthermore, the role of neuroleptic treatment in influencing certain aspects of psychomotor performance cannot be overlooked (46). This point is further emphasized in a research investigation by Zhuo et al. (46), which found that certain antipsychotic medications were associated with worsened motor functioning in individuals diagnosed with schizophrenia (38, 47). These consistent findings underscore the prevalence of motor deficits in schizophrenic individuals.

According to our research findings, both groups demonstrated a significant melioration in verbal memory following the COVID-19 period. This improvement can be attributed to administering remediation treatment or antipsychotic medications. These findings align with a separate cohort study by Tensforde et al. (47), which also reported a notable enhancement in verbal memory in schizophrenic patients following the onset of COVID-19 (47). Additionally, another meta-analysis examined the impact of antipsychotic medications on cognitive abilities and found that certain antipsychotic drugs were linked with improvements in verbal memory, supporting our findings (48). Contrary to our findings, a study by Lin et al. (49) reported no substantial spike in verbal memory in patients with schizophrenia following the COVID-19 period (49). This discrepancy may be due to differences in sample size, treatment approaches, or other factors that should have been accounted for in our study. To obtain a more comprehensive understanding of the factors that impact verbal memory in individuals diagnosed with chronic schizophrenia, it is necessary to conduct additional research using larger sample sizes and controlled experimental designs. Additionally, exploring the potential impacts of anti-psychotic medications on cognitive function over an extended period in this population would provide valuable insights.

It is pertinent to emphasize that there were no significant changes in the prevalence of depression among patients before and after COVID-19. This suggests that the individuals in our study did not have depressive thoughts or psychological reactions specifically related to the virus. It is possible that patients living in a community setting did not face the same level of anxiety and stress associated with the COVID-19 pandemic. Previous studies have established significant associations between viral illnesses like varicella-zoster virus, herpes simplex virus, hepatitis C, influenza A(H1N1), HIV/AIDS, and the development of anxiety and depression (50). These findings suggest that viral infections can hurt mental health. Concerning our study, however, it is crucial to acknowledge that the effects of viral infections on mental health can vary based on the specific virus and individual factors. A study found that individuals infected with the varicella-zoster virus had a high risk of developing depression in comparison to non-infected individuals (51).

Similarly, a survey claimed a monumental association between HIV/AIDS infection and increased rates of anxiety and depression (52). Therefore, while our research did not observe a substantial association between the period of COVID-19 and depression among individuals diagnosed with schizophrenia, it is crucial to acknowledge that viral infections can have diverse effects on mental health. Additional investigation is warranted to delve into the precise mechanisms that connect viral infections and mental well-being outcomes in individuals with persistent schizophrenia.

Furthermore, our results revealed that the patient's daily functioning remained stable and unaffected before and after COVID-19. This phenomenon may be attributed to individuals with schizophrenia who reside in clinical settings often experiencing restricted community engagement and occupational performance opportunities, leading to a more sedentary lifestyle. It is worth mentioning that there was no notable alteration in the utilization of antipsychotic medications before and during the COVID-19 period. These results concord with a study by Anderson et al. (2023), which reported that individuals with schizophrenia who maintained regular medication adherence had a reduced risk of COVID-19 infection and demonstrated better overall health outcomes (9). Previous findings also revealed that individuals with psychiatric conditions who adhere to their medication regimen have a lower chance of getting COVID-19 and tend to experience more favorable outcomes if they become infected compared to the general population (53). Additionally, a comprehensive analysis by Brown et al. (8) highlighted that anti-psychotic medication adherence was associated with improved clinical outcomes and reduced hospitalizations in patients with schizophrenia (54).

The regression analysis results suggest that insomnia and the relationship of a COVID-19 diagnosis with preexisting cognitive function predict cognitive function following the COVID-19 period. This interaction may be attributed to the immune-inflammatory response caused by the virus. Several studies have provided evidence supporting the role of immune-inflammatory processes in cognitive impairments across various neuropsychiatric disorders (55, 56). Inflammation has been identified as a significant neuropsychological process contributing to cognitive decline. Some studies support the notion that COVID-19 can lead to cognitive impairments; other studies have reported conflicting findings. For instance, a recent study found no significant association between COVID-19 and cognitive function in individuals with schizophrenia (3).

Similarly, a meta-analysis reported mixed results regarding the consequence of COVID-19 on cognitive function, with some studies showing impairments and others showing no significant effects (4). Research has shown that low-grade inflammation is intertwined with cognitive impairment in individuals with schizophrenia (1). Furthermore, chronic insomnia has been linked to impairments in attention, memory, executive function, and overall cognitive performance (57). Hence, the coexistence of insomnia and the interplay between a COVID-19 diagnosis and pre-existing cognitive function could contribute to the cognitive impairments observed in individuals following the COVID-19 period. These contrasting findings emphasized the need for more research to understand better the relationship between COVID-19 cognitive function and insomnia in individuals with schizophrenia.

In summary, the available evidence indicates that insomnia and the interplay between a COVID-19 diagnosis and pre-existing cognitive function may potentially impact cognitive abilities in individuals with schizophrenia following the COVID-19 period. However, it is essential to note that the existing literature presents conflicting results. Therefore, further study is requisite to establish a more evident apprehension of the connection between COVID-19, insomnia, and cognitive function in this specific population. Additionally, future studies should uncover the underlying mechanisms contributing to these associations.

Limitations

It is important to acknowledge several limitations of the study that should be taken into account when interpreting the findings. Firstly, the relatively small sample size of 219 patients may limit the generalization of the results to a larger population of individuals with schizophrenia. Additionally, the study was conducted in a specific cultural and geographical context (Mayo Hospital, Lahore, Pakistan), which introduces potential selection bias and restricts the applicability of the findings to other healthcare settings. Furthermore, the follow-up period of approximately 6.52 ± 1.94 months may not be long enough to capture the long-lasting impact of COVID-19 on cognitive functions in individuals with schizophrenia. Lastly, the absence of a control group of individuals without schizophrenia makes it arduous to isolate the specific impact of COVID-19 on cognitive changes in this population.

Conclusion

The findings of our investigation indicate a significant decrease in objective cognitive functioning among individuals diagnosed with both schizophrenia and COVID-19. The transmission of the virus has been observed to exert a discernible impact on various cognitive facets, encompassing verbal memory, working memory, and overall cognition. Individuals diagnosed with COVID-19 demonstrated significantly more prominent impairments in these areas compared to those individuals who were not infected. Insomnia has emerged as the predominant determinant in predicting cognitive deterioration, compounded by the interaction of a COVID-19 diagnosis and existing global cognitive functioning. Additional investigation is required to acquire a comprehensive comprehension of the cognitive disparities observed in individuals diagnosed with schizophrenia who have been impacted by the COVID-19 virus.

Data availability statement

The original contributions presented in the study are available upon reasonable request. Further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved and conducted by the guidelines of the Declaration of Helsinki and the Ethics Review Committee of Mayo Hospital, Lahore, Pakistan (approval: MH-98975/29). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AM: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft. ALA: Conceptualization, Investigation, Methodology, Resources, Validation, Writing – review & editing. ABA: Conceptualization, Data curation, Funding acquisition, Investigation, Project administration, Writing – review & editing. FZ: Investigation, Methodology, Resources, Supervision, Validation, Writing – review & editing. IA: Writing – review & editing. BS: Conceptualization, Investigation, Resources, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Risk communication and community engagement in the context of COVID-19 response in Bangladesh: a qualitative study

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Background: The global COVID-19 pandemic profoundly impacted nations worldwide, and Bangladesh was no exception. In response, the government of Bangladesh implemented community awareness initiatives aimed at containing the spread of the virus, aligned with international guidelines and recommendations. Despite these efforts, a lack of comprehensive community awareness programs played an essential role during the pandemic, not the preventive measures. A qualitative study employing framing theory was conducted to gain a deeper insight into how the social context influenced risk communication and community response throughout the COVID-19 pandemic in Bangladesh.

Methods: The study was conducted in four selected districts of Bangladesh from February to May 2022 using complementary data collection methods, including key informant interviews, in-depth interviews, and focus group discussions with purposely selected participants. Data were analyzed thematically by following six steps of the thematic analysis process. Codes were developed based on the data and summarized into themes and sub-themes grounded on the codes.

Results: The findings indicate that the government of Bangladesh, along with development partners and non-government organizations, made a significant effort to raise awareness about COVID-19 in the community. However, there were certain limitations to this effort. These include a lack of social science and public health approaches to understanding the pandemic; inadequate coordination among the authorities for COVID-19 prevention and control; technological and geographical barriers for disseminating messages; the living conditions and lack of facilities; socio-cultural norms in understanding the COVID-19 health messages, and the gendered understanding of the messages. The findings also revealed that the awareness activities remained a one-way approach to inform the people and faced challenges to actively engage and create ownership of the community in the pandemic response.

Conclusion: The study identified gaps in implementing risk communication and community engagement strategies in Bangladesh during the COVID-19 pandemic. Increasing focus on public health and prioritizing community ownership is essential to designing a more effective community awareness campaign. This approach will help ensure that health messages are communicated effectively and tailored to different communities' needs.

KEYWORDS

COVID-19, risk communication, community engagement, framing theory, qualitative research, Bangladesh

Background

The novel coronavirus disease (COVID-19) has been a significant incident, with outcomes ranging from actual deaths to the collapse of the world economy (1, 2). Due to increased infections and fatalities, the World Health Organization (WHO), on March 11, 2020, declared it a global pandemic. In order to stop the pandemic, the WHO pleaded with governments to follow its recommendations, which include ordering people to "stay at home" and testing as many people as possible who had symptoms of COVID-19 (3).

Bangladesh was one of the countries affected by COVID-19. On March 8, 2020, the government of Bangladesh officially recognized the first COVID-19 case. From that point, the number of infections and fatalities steadily climbed, following the global trend (4). The government launched several programs to address the issue and to contain the pandemic. The initiatives included, among many others things, providing personal protective equipment (PPE) and other logistics for healthcare professionals and identifying and treating COVID-19 patients. The government also organized regular press briefings to inform people about the response to the pandemic and how to prevent and control infections and deaths (5, 6).

In order to contain the pandemic, the World Health Organization (WHO) strongly emphasized the importance of community engagement in its public health-related initiatives and recommendations. For instance, the COVID-19 strategy emphasizes community involvement in the risk communication (7). The strategy focuses on establishing preventive behaviors like hand washing, refraining from touching one's face, practicing good respiratory hygiene, maintaining distance, isolating confirmed cases in a community facility or home, and cooperating with physical distancing measures and movement restrictions when necessary. Incorporating local input and circumstances into health care services, encouraging community-level education, and focusing on community empowerment and mobilization are other key components of the plan. Additionally, the WHO strategy strongly emphasized disseminating accurate information regarding hazards, the steps that should be taken by health authorities, and the precautions individuals could take (7) Considering the WHO priorities, The Government of Bangladesh also emphasized community engagement in its COVID-19 prevention and control activities.

The principle of community engagement or participation in Bangladesh's health sector was a pre-COVID issue (e.g., Community Support Committee-CSC for hospital management) (8). It was reinforced during the pandemic because of the enormous public health concern worldwide (9).

The Government of Bangladesh prioritized community engagement in its national COVID-19-related initiatives and guidelines, in keeping with international recommendations and advice (10–13). The "Risk Communication and Community Engagement (RCCE)" portion of the "Bangladesh Preparedness and Response Plan for COVID-19" placed a strong emphasis on enabling people and communities to control the spread of COVID-19 by changing behavior and taking coordinated community action (13). The government, several development partners, and NGOs also raised public awareness by involving communities in preventing and controlling infections. They did this, for instance, by mandating mask use, hand hygiene, and social distancing. An NGO-led effort named "Community Resilience to Prevent Coronavirus" focused on educating local leaders, volunteers, and community groups while including them in awareness campaigns with the help of business, public, and non-governmental organization (NGO) partners (14). The effort produced communications material and messages of a wide variety and disseminated them through various media outlets, including radio and television, billboards, social media, local government officials, and religious leaders (15).

Despite these engagement efforts, the country's overall COVID-19 status indicated low community awareness of the virus, contributing to higher infection rates in many locations–urban and rural (16, 17). A further investigation found that the delta variant of the virus, initially detected in India, had made its way into Bangladesh via the land border. Subsequently, during the Eid ul Fitr festival in May 2021, it spread extensively to other districts, primarily due to a lack of awareness among the general public (18).

A number of studies conducted in Bangladesh explored social and community perceptions regarding the prevention and control of coronavirus. One such study in rural Bangladesh revealed a lack of comprehensive knowledge about the spread, symptoms, and prevention of the virus (19). Additionally, there existed a disparity between community beliefs concerning the pandemic and the science-driven interventions advocated by health professionals (20). In another study focusing on social and cultural beliefs related to COVID-19 in Bangladesh, the critical role of community engagement was highlighted in ensuring the effective implementation of COVID-19 prevention programs (21).

The COVID-19 virus transmission is best prevented and controlled through vaccinations. Although there is always a chance of illness despite vaccination, the government of Bangladesh has made good progress in immunizing the population (22). These facts have led many specialists to underline the need for improved and expanded community awareness campaigns to limit coronavirus transmission (17). As COVID-19 continues to be a global concern and there is concern over a potential future wave, thorough implementation of the health safety requirements is also crucial (23).

Within this context, the primary objective of this study was to present comprehensive findings on community perceptions, preparedness, and responses to COVID-19 health guidelines. Additionally, the study aimed to assess awareness activities within selected districts in Bangladesh, providing valuable insights into the effectiveness of these initiatives.

Framing theory

Through the lens of framing theory, we conducted a qualitative study to understand how the social context influences risk communication and community response during the COVID-19 pandemic (24, 25). Framing theory is founded on the basic assumption that an issue can be perceived from various perspectives and that people form opinions based on their previously held beliefs. Further, it refers to how people construct a particular understanding of an issue and act based on their perspective of the problem (24). In summary, framing theory emphasizes the importance of how information is provided to the community and the context in which it is presented. Both of these can significantly influence the community's understanding, perceptions, and actions, especially in the domain of public health. Recognizing and understanding the

power of context or frame is essential for governments, media organizations, and public health officials in effectively communicating and managing health crises and promoting healthier behaviors (24). Framing theory have been applied to various research areas in the field of health, including community response to vaccination, health communication, the use of alcohol, and sexual and reproductive health (25, 26). However, a comprehensive analysis of risk communication in Bangladesh throughout the pandemic has not yet been conducted. The Bangladesh Health Sector Response to an Emergency Plan for Novel Coronavirus recommended communication as one of the effective strategies for limiting the spread of viruses, and the lack of an evaluation is an issue.

Methods

Study design and site

In-depth interviews (IDI) and focus group discussions (FGD) were complementary data-gathering methods employed in this qualitative study. Bangladesh, a densely populated country middle-income country with an estimated population of 165 million, faced a serious challenge dealing with the COVID-19 pandemic.

This study focused on the collection of primary data from four purposively selected districts between February and May 2022, with a particular emphasis on three divisions that reported the highest COVID-19 cases: Dhaka (70.5%), Chattogram (12.8%), and Rajshahi (4.2%) divisions. Dhaka, the capital of Bangladesh, is known as having one of the largest and most densely populated slum areas. In the Dhaka district, the infection rate was 60.6%, highlighting the urgency of examining the dynamics of the pandemic in urban settings and in vulnerable urban communities in particular. Kishoreganj, situated in the Dhaka division, is characterized by wetlands and a hard-to-reach area due to its geographical features. The district has areas of high poverty, and investigating Kishoreganj provides insights into the challenges other similar regions faced during the pandemic. In the Chattogram division, Cox's Bazaar is recognized as a popular tourist destination, which made it susceptible to the spread of the virus. This district's inclusion in the study allowed for an examination of the pandemic's impact on tourism-dependent regions. Under the Rajshahi division, the Pabna district emerged as one of the areas severely affected by the pandemic.

Study sampling and participants

We conducted 36 IDIs, 14 KIIs, and 8 FGDs at various study sites (Figure 1). The KIIs included civil surgeons, district-level health education officers, sub-district-level health and family planning officers, residential medical officers, as well as local civil society organization (CSO) members and pertinent national specialists. These KIIs were chosen purposively. They were all involved in the prevention and control of COVID-19. The KIIs were used to investigate the government effort in response to the community awareness program during the COVID-19 pandemic, including the strategies for promoting good hygiene at the community level and coordination of the activities with ministries working during the emergency period. Aspects of the community awareness program and factors that encouraged community members to adopt preventive measures and obstacles to carrying out the program's operations were investigated.

In-depth interviews were conducted with male (n = 22) and female caregivers (n = 14) in communities to explore actual knowledge, practice, drivers, and barriers to handwashing and use of facemasks. We purposely targeted both females and males for their professional responsibilities as care providers. The IDIs included males and females with diverse characteristics (farmers, daily laborers, transport workers, garment workers, and businesspersons) all of whom were exposed to different awareness messages related to COVID-19. The FGDs were conducted separately with males (n = 4) and females (n = 4) to capture the perception, preparedness, and response to COVID-19. Each FGD session consisted of eight participants, and there were a total of 64 participants in the eight FGDs. We purposely selected communicative residents who were available during the day to participate.

Data collection procedure

For KIIs, IDIs, and FGDs, we developed separate open-ended interview guidelines, which were used to collect the data. The interviews focused on four major themes: (a) knowledge and practice regarding the COVID-19 awareness messages among the study participants; (b) facilities available within the public places and residences; (c) challenges to adherence to the preventive measures; and (d) suggestions and recommendations to meet their needs. The researchers used follow-up questions based on the interviewees' responses to the initial open-ended questions to elicit more information about the respondents' specific experiences. The combination of open-ended and probing questions facilitated more in-depth conversations between the researchers and the respondents.

Three qualified research officers with a background in Anthropology or Sociology were trained to conduct interviews in the local language—Bengali—under the supervision of the study's principal investigator (SA). Before the beginning of data collection, a three-day "Research Methods Workshop" was organized. SA led the workshop for the investigation. It included (1) an overview of qualitative research methods, (2) practice undertaking interviews using open-ended guidelines, (3) writing transcripts, and (4) ethical procedures. The interviews (KIIs, IDIs, and FGDs) were conducted face-to-face at the respondents' preferred times and locations. All interviews were recorded with a digital recorder. The fieldwork for data collection was conducted under the supervision of SA, who has academic training and experience conducting qualitative research. The researcher (MK) oversaw the data collection from the field, including conducting the KIIs at all field sites. One researcher (SA) moderated the FGDs, while another (MK) took comprehensive notes alongside the FGD recordings.

The steps in preparation for the field research included pre-testing and adaptation/revision of the study data collection instruments (27). During the pre-testing, the interviewers kept a record of their experiences in the field—what they observed during the interviews—and shared it in the debriefing session for the team's learning. This procedure helped to assess and review the mode of conducting interviews and discussions with the respondents and to identify any biases during the interviews.

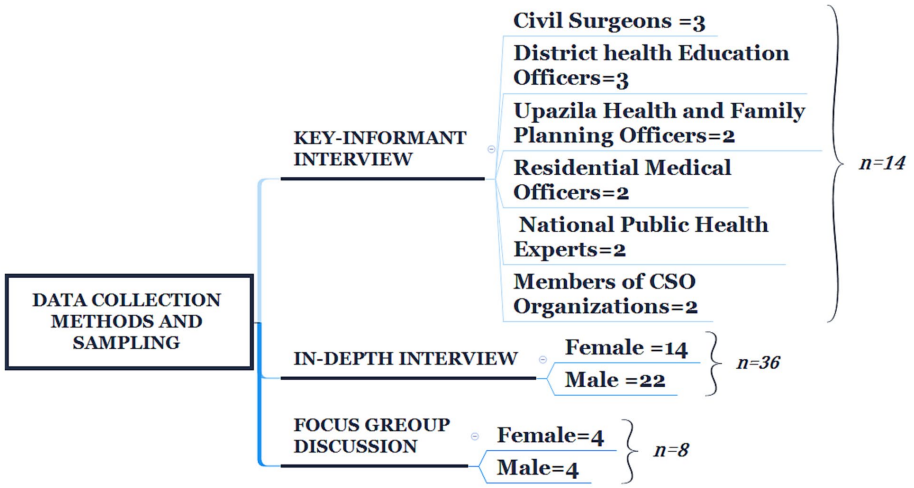

FIGURE 1
Data collection methods and sampling.

Data analysis

Data analysis followed a rigorous process of thematic analysis (28, 29). Two research assistants transcribed all recorded interviews without participant identification information. The transcripts were then imported into Atlas-ti software version 7.2 for further analysis. SA and MK followed a systematic six-step process, aligned with established guidelines (27). The process commenced with listening to a subsample of transcripts to verify their accuracy and consistency. SA and MK independently coded the data by reading and re-reading the transcripts to ensure the robustness and reliability of the analysis. Subsequently, the two authors engaged in discussions to reach a consensus on common codes and themes. Initially, deductive coding was performed to identify themes based on interview questions. Interviews and group discussions yielded additional themes that were identified inductively. To reach a consensus on the data interpretation, the researchers discussed and compared the similarities and differences of the coded data. Based on their conversations, they compiled a list of shared codes for themes (Figure 2). Most themes from the IDIs, KIIs, and FGDs overlapped across groups and interviews. We have merged themes based on the similarities and differences of the data from the IDIs, KIIs, and FGDs and presented the results in depth.

Results

Background information about the study participants

Table 1 presents the socio-demographic information of the participants who participated in the individual in-depth interviews (IDI) and focus group discussions (FGD). The most common occupation among the male participants was day laborer, while most of the female participants were housewives. Some of the male participants had small businesses as their occupation. On average, the participants had three children. Most participants were married, though 12 of the female participants were either divorced or widowed. Most participants had completed education between grades 6 and 10, and 11 participants had completed education beyond grade 11. The average monthly income reported by the respondents was USD 155.

Theme-1: Government and non-government activities regarding community awareness programs

The first theme presents the community awareness program implemented by the government and non-government organizations. It comprised two sub-themes: (i) Lack of social science perspective to understand the pandemic of COVID-19, and (ii) insufficient coordinated government efforts for COVID-19 prevention and control. The data showed that the government, development partners, and NGOs made tremendous efforts to increase community awareness for the prevention and control of COVID-19. The attempts adopted interpersonal and mass communication approaches to reach communities through social, print, and electronic media. The activities (Table 2) included the distribution of facemasks, the establishment of communal handwashing facilities, and a campaign to maintain respiratory etiquette and social distancing.

Lack of social science perspective to understand the pandemic of COVID-19

All KIIs reported that most measures focused on clinical features of COVID-19: identifying and detecting infectious cases; isolating the cases; calculating the infection rates; establishing hospital facilities to treat infectious patients; and establishing testing facilities. These clinical measures were necessary, but the pandemic was not just a clinical event. It had social dimensions and consequences. The government invested considerable resources to educate people about

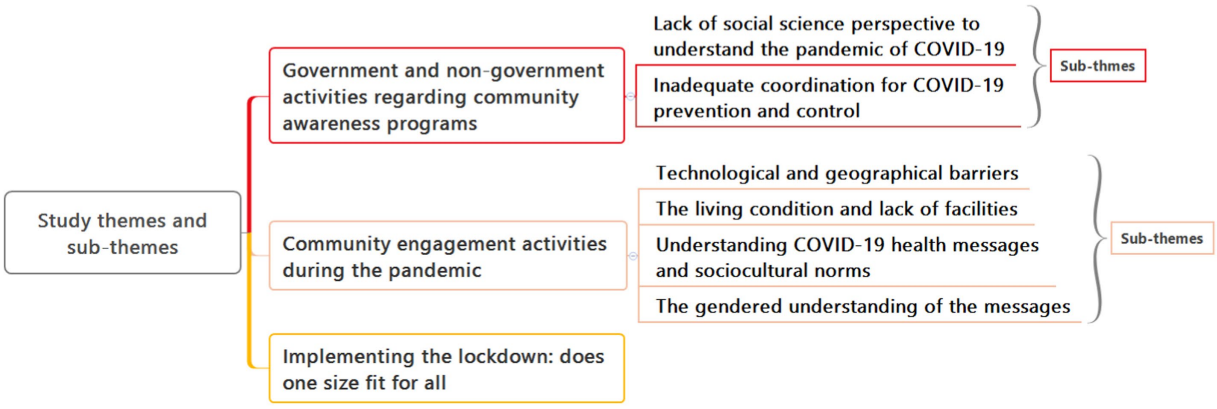

FIGURE 2
Study themes and sub-themes.

TABLE 1 Social and economic background information of IDI and FGD participants.

Variables	N = 100
Sex	
Male	55
Female	45
The average age of the participants	45
Religion	
Muslim	90
Hindu	10
Years of education	
None	0
1–5	32
6–10	48
11+	20
Marital status	
Married	88
Divorced/widow	12
The average number of children	3
Occupation	
Housewife	35
Small business	30
Day laborer	35
Average income/month (USD)	155

prevention, but people's responses to those measures did not meet expectations because of their socio-cultural beliefs about the disease and conditions. In addition, the government formed different technical committees comprised of clinicians and administrative personnel. The participation of sociologists and anthropologists in the committee was not seen as necessary and, hence, the committees were not effective.

Inadequate coordination for COVID-19 prevention and control

The key informant interviews (KIIs) showed that the implementation of the COVID-19 prevention and control measures in Bangladesh was led by the Ministry of Public Administration despite the Directorate General of Health Services (DGHS) (30) being the responsible authority. The government's priority area of "risk communication and community engagement (RCCE)" was not adequately addressed due to the absence of a dedicated and functional unit or section to carry out this work. Additionally, the Bureau of Health Education of DGHS—which was primarily responsible for health promotion activities—had limited engagement, as reported by the respondents. The government relied heavily on NGOs for community awareness activities, neglecting its ownership of other critical activities such as testing, treatment, and vaccination. In this regard, one KII said,

> *"It would be better to engage or make the Bureau of Health Education a focal for community engagement work, but it did not happen. Still, the Bureau of Health Education is not on board for health education. I think there was a need for a professional approach in the risk communication and community engagement work, but such an approach was absent. Different institutions are working, but those are still scattered and not coordinated."*

Theme 2: Community engagement activities during the pandemic

The second theme revealed that mass community awareness activities were conducted but were not successful in engaging communities. The findings showed that community awareness activities were a one-way communication. Information was circulated to the people, but because of several challenges, it was not supplemented with community engagement. One of the challenges was the lack of access by the community to the necessary technology to receive preventive messages disseminated through different media.

TABLE 2 Summary of the "Risk Communication and Community Engagement (RCCE)" messages distributed in the study areas.

Key messages related to RCCE	RCCE activities
Washing hand	With support from development partners, the government's authorities set up communal hand washing stations in different public places such as the entrance of hospitals, municipality and administrative offices, markets, and bus stations.
Wearing facemask	Messages were communicated through mass media campaigns to wear facemasks to prevent infection. The government and non-government organizations distributed facemasks to the community residents in the study areas.
Maintaining social distancing	Media campaigns and interpersonal communication circulated messages around maintaining social distance and practicing hygiene etiquette.
Lockdown to restrict movement	Mass campaign on 'stay at home' and restriction mobility of people by the shutdown of public transportation; also, deployment of law enforcement agencies to ensure restriction of movement during the lockdown.

Geographical barriers, such as remote locations, hindered community engagement efforts. In addition, the population's living conditions made handwashing and maintaining social distance challenging, restricting people's ability to adhere to the awareness messages effectively. Furthermore, socio-cultural norms and beliefs influenced the community's engagement with the prevention activities. This theme covers four sub-themes: technological and geographical barriers, living conditions and lack of facilities, understanding of COVID-19 health messages, socio-cultural norms, and the gendered understanding of the messages.

Technological and geographical barriers

All the KIIs reported that the awareness activities were primarily conducted in urban areas, which had the highest infection rates. They added that the lack of awareness activities in the rural areas created a belief that the coronavirus did not exist in the villages. A similar opinion was shared by the IDI and FGD participants. They indicated that community awareness activities predominantly focused on urban areas, particularly Dhaka, where urban people could access online information and had greater access to more virtual media. In contrast, rural areas were less familiar with the online awareness activities happening within their localities. The respondents in remote areas in the study districts, such as wetland villages in Kishoreganj, some hilly pockets in Cox's Bazaar, and riverine villages in Pabna, gained knowledge about awareness campaigns through television and radio. The participants from these rural areas also said they have limited access to social media, and the health workers did not visit their houses to make them aware due to the ongoing movement restrictions.

> One KII participant said, *"Our awareness activities at the beginning were in Dhaka and megacities. The infection rate was high in Dhaka, the country's most populated city. All efforts were made to make aware the city people. It created the misconception that corona does exist in villages. Risk communications and community engagement is not a one-way factor. Communication should be two-way. Like circulating information, the one-way communication was excellent but lacked community engagement."*

One IDI participant said,

> *"Yes, there are many activities in the town. But what about the rural area? Kishoreganj has many villages in the wetlands (haor). These villages are difficult to reach due to their remoteness. I do not think such awareness activities are conducted in the villages."*

The living conditions and lack of facilities

All participants shared that they could not practice handwashing, isolation, and social distance as they lived in slums and did not have the required facilities within their homes. They use shared toilets and kitchens with other families. Key informants reported that considering the living and working conditions of the poor people and day laborers, the government and NGOs established communal handwashing stations with soap and water in public places such as bus and train stations, hospitals, and local markets. Awareness activities were conducted by loudspeakers to promote handwashing with soapy water. The IDI and FGD participants reported that the communal handwashing stations were non-functional, and lacked running water or soap. In contrast, the key informants reported that they frequently experienced the stealing of water taps and soap from the public handwashing stations. They also mentioned the budget constraints to keep the communal handwashing stations functional.

Understanding COVID-19 health messages and socio-cultural norms

The participants in the study had varying beliefs about the effectiveness of facemasks to prevent COVID-19. The IDI and FGD participants knew the importance of wearing facemasks, practicing hand hygiene, and social distancing as key messages to prevent the spread of COVID-19. However, they lacked an understanding of isolation and quarantine measures. The participants appreciated the government's distribution of free facemasks. However, they only wore them when compelled to do so by law enforcement.

Most participants believed in Allah's power to create and cure diseases. Thus, if Allah wished them to die from the virus, they could not prevent death by wearing masks and washing their hands. While some believed wearing a facemask could protect them from the virus, others felt masks were only effective if Allah wanted to save them from the disease. Some participants believed the coronavirus spreads through the dust so that a facemask would save them from the virus. In this regard, one respondent said,

> *"Allah has ultimate authority over everything, even diseases like COVID-19, and controls life and death. Nothing can save our lives if Allah wants us to suffer from the virus. Whether we wear a mask or not, we will be saved if Allah decides."*

The gendered understanding of the messages

The study revealed a gender difference in understanding and practicing the key health messages. Most participants believed that women were less likely to get infected by the coronavirus than men because they stayed home and had more opportunities to clean their hands while performing household chores such as cooking in the kitchen and washing utensils and clothing. Some participants mentioned that women wear hijab, which, in their opinion, was 'a kind of facemask' because it covered their face, including their mouth and neck. Because of this view, men did not feel they could infect a woman in the family after returning home from outside. The female study participants said they took no precautionary measures to prevent the virus. This gender dimension further contributed to the weak adherence to "social distancing" in the family—when a husband gets infected, his wife must take care of him, staying closely in the same room. One FGD study respondents said,

> *"Women have a low risk of getting infected from coronavirus as they stay home, clean their hands, and frequently work in the kitchen. He added, "Women wear hijab, and the hijab is their facemask to protect against coronavirus. Women always clean their hands as they cook and are safer than men."*

Theme 3: Implementing the lockdown: does one size fit for all?

All participants in individual and focus group interviews expressed a wish to avoid lockdowns because they would lose income. The study revealed that the IDI and FGD participants strongly opposed the government's decision to implement lockdowns. Respondents mentioned concerns about their livelihoods and financial stability as their main reasons for disagreeing with lockdowns. The participants believed that prolonged lockdowns would lead to starvation rather than protection from the COVID-19 disease. Participants shared that they faced significant financial difficulties during the lockdown period, which kept them out of work.

Additionally, many respondents reported severe financial hardship and food shortages due to the lockdown. Although the government and NGOs distributed relief, respondents perceived the support (provided in the form of rice, potatoes, pulses, and vegetable oil) as insufficient to meet their daily needs. Consequently, respondents admitted to breaking government regulations, such as movement restrictions, to earn enough money to survive.

One of the IDI respondents said,

> *"What will I eat if I stay at home for days? How will my family run without an income? Will the government feed us for months? No. So, I must go out to earn."*

Another respondent said,

> *"I felt like I was in jail during the time of lockdown. I could not work for three months due to the lockdown. It was a horrible situation for my family and me. We suffered from starvation as there was no income."*

Discussion

The study's findings indicate what to do more and how to better promote effective risk communication and community engagement in countries like Bangladesh to prevent and control COVID-19 and other infectious diseases. Community engagement was an essential part of the WHO's strategy for COVID-19 (7). While this strategy focuses on community empowerment, mobilization, and consideration of local contexts in health care services, the study findings reveal that such focuses needed to be more coherent and better coordinated in Bangladesh. The fragmentation was also apparent in people's compliance with Bangladesh's national response plan for COVID-19 and the government's priority on community participation in healthcare services (13).

The findings critically draw attention to the absence of a public health approach, which had been a central concern in the country's health systems (31). There is a sharp difference between "health" and "public health." According to a WHO definition, 'public health' is the "art of applying science in the context of politics to reduce inequalities in health while ensuring the best health for the greatest number." (31) Bangladesh's National Health Policy 2011 uses the term "public health" to "ensure collective and coordinated efforts of different ministries and divisions and the private sector engaged in public health and medical services." (32) Krishnan, Kapoor, and Pandav argue that clinicians deal with individuals while public health experts deal with communities, and they emphasize the role of health systems for the prevention and promotion of health (33). Even though COVID-19 was a public health concern, the study found that a public health approach was absent or weak in the COVID-19 awareness activities.

The Ministry of Health and Family Welfare (MoH&FW) is the main agency responsible for delivering health services in Bangladesh. It is responsible for policy planning and implementation, regulating standards, and ensuring people's health (30). The Ministry also has a community participation approach to health care services in line with the Alma Ata declaration (8). However, a lack of institutional ownership to strengthen community participation and engagement in COVID-19 prevention and control is a concern. The MoH&FW has its community health workforce in a rural setting; however, the whole structure was to deliver health services, not engage the community in the services. This difference between what was done and what should have been done was a severe challenge—a challenge also observed in other studies which argued that community engagement was necessary for better prevention and control of COVID-19 (17).

Bangladesh has made significant economic progress over the years. The World Bank estimated that GDP had increased year-on-year by 1.6% between 1990 and 2019, the last year before the pandemic (34, 35). This economic progress supported the economic transition from a least developed country (LDC) to a Lower-Middle-Income Country (LMIC) (36). Despite the progress, the economic shocks of COVID-19 were severe; many lost their livelihoods, and it became a challenge to implement COVID-19 health guidelines targeting the communities effectively (37). People's health vulnerability was an issue in the government's social safety net programs to provide economic support for low-income citizens (38). However, Bangladesh's National Social Security Strategy had not adequately focused on health emergencies compared with its focus on poverty, climate change, and disaster (39). In the context of a pandemic like COVID-19, the social

security strategy must also ensure economic support for the poorer section of people during any community awareness intervention.

Equity and equality are crucial and integral to an effective health system response to a pandemic. Bangladesh's national health policy explicitly focuses on health equity and equality (32). Different operational plans and strategies of Bangladesh's health services authority emphasize the needs of poor, vulnerable, and marginalized groups of people in health services delivery (40). However, our results showed that the COVID-19 awareness activities were biased toward urban areas while the hard-to-reach areas were left out. Women and people in hard-to-reach areas had less access and greater difficulty accessing health services and this disparity intensified during the pandemic (41). This empirical outcome stands in sharp contrasts to the MoH&FW's health policy and the gender equity strategy, which aim to ensure health equity and gender-responsive health services delivery in the country (42). We would argue that community awareness interventions on health matters should address this (in) equity and (in)equality in reaching the people. This is particularly important when one's vulnerability in a pandemic like COVID-19 goes beyond biological issues and involves socioeconomic issues as well. Any public health intervention, including the Social and Behavioral Change Communication (SBCC) campaign, should consider this broader aspect for its maximum reach and coverage.

Our findings, importantly, draw attention to the notion of "info-demic" as the people in different study areas understood COVID-19 health messages differently (43). WHO used the term "info-demic" to describe the situation of misinformation during COVID-19, which led to confusion, panic attacks, and anxiety among the people (44). Such misinformation is uncontrolled and a barrier to implementing policies and guidelines during a pandemic (43). This info-demic is rooted in people's socio-cultural beliefs. The study findings revealed that the people received and interpreted the COVID-19-related information in various ways. It often involved people's cultural beliefs, such as connecting them to their religion (Islam), particularly the "power of Allah."

The paper provides lessons for future community awareness design issues in a pandemic like COVID-19 in a country like Bangladesh. The lessons include an- equal emphasis on disseminating information and ensuring a common understanding of the information; capitalizing on community strength; utilizing various community-based platforms for health education; increasing focus on the hard-to-reach areas; strengthening and continuing collective and collaborative action; considering socioeconomic situations of the target vulnerable populations; and integrating cultural perspectives into community awareness intervention.

Limitation

The study had three notable limitations. Firstly, the study was conducted in specific areas of Bangladesh, and the findings may not be generalizable to other regions. Secondly, the study did not assess the *effectiveness* of community awareness interventions in preventing or controlling COVID-19. Finally, the study did not explore the impact of the pandemic on other health issues and the healthcare system in Bangladesh. Despite these limitations, the study provides valuable insights into community engagement and risk communication strategies in the context of a pandemic like COVID-19 in Bangladesh.

Conclusion

The discussion critically analyses the study's findings on community engagement and public health approach in COVID-19 prevention and control in Bangladesh. It highlights the fragmentation in the community empowerment and mobilization strategy and the absence of a public health approach in COVID-19 awareness activities. The discussion also emphasizes the need for institutional commitment to strengthen community participation and engagement in COVID-19 prevention and control and the role of socioeconomic factors, equity, and equality in the health system response.

The discussion further underscores the importance of considering socio-cultural beliefs and integrating cultural perspectives in community awareness interventions to address the "info-demic" in a pandemic like COVID-19. It is crucial to consider different needs, contexts, and priorities when developing public health interventions and policies related to pandemic control. A one-size-fits-all approach may not effectively address various communities' diverse challenges and experiences. The discussion concludes by providing future design issues for community awareness in a pandemic, including a common understanding of information, capitalizing on community strength, utilizing community-based platforms for health education, focusing on hard-to-reach areas, continuing collective and collaborative action, and integrating cultural perspectives into community awareness interventions.

The paper also calls for more research to be done from a public health perspective, to learn more about how the government of Bangladesh's institutions can work together better to make its community participation approach to health service delivery effective. It is important for a community-based health system to be resilient to prevent future pandemics and communicable diseases.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The Ethical Review Committee (ERC) of the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) reviewed and approved the study proposal (PR-21135). The study adhered to the ethical guidelines of the authors' institution for research. Participants provided informed written consent following the regulations of the ERC. The participants agreed to publish data from the interviews in a non-identifiable form.

Author contributions

MK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. AR: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. DR: Project administration, Writing

– review & editing. SA: Funding acquisition, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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Prevalence, attitudes and concerns toward telepsychiatry and mobile health self-management tools among patients with mental disorders during and after the COVID-19 pandemic: a nationwide survey in Poland from 2020 to 2023

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Introduction: Mobile Health (mHealth) is a rapidly growing field of medicine that has the potential to significantly change everyday clinical practice, including in psychiatry. The COVID-19 pandemic and technological developments have accelerated the adoption of telepsychiatry and mobile solutions, but patient perceptions and expectations of mHealth remain a key factor in its implementation.

Aim: The aim of this study was to assess (1) the prevalence, (2) attitudes, preferences and (3) concerns about mobile mental health, including telepsychiatry and self-management tools, among patients with mental disorders over the period 2020–2023, i.e., at the onset, peak and after the expiration of the COVID-19 pandemic.

Materials and methods: A semi-structured survey was administrated to 354 patients with mental disorders in Poland. The questions were categorized into three section, addressing prevalence, attitudes, and concerns about telepsychiatry and mobile health self-management tools. The survey was conducted continuously from May 2020 to the end of May 2023.

Result: As many as 95.7% of patients with mental disorders used mobile devices at least once a week. Over the course of 3 years (from 2020 to 2023), there was a significant increase in the readiness of patients to embrace new technologies, with the percentage rising from 20% to 40%. In particular, a remarkable growth in patient preferences for telepsychiatry was observed, with a significant increase from 47% in 2020 to a substantial 96% in 2023. Similarly, mHealth self-management tools were of high interest to patients. In 2020, 62% of patients like the idea of using mobile apps and other mobile health tools to support the care and treatment process. This percentage also increased during the pandemic, reaching 66% in 2023. At the same time, the percentage of patients who have concerns about using m-health solutions has gradually decreased, reaching 35%

and 28% in 2023 for telepsychiatry and for the reliability and safety of m-health self-management tools, respectively.

Conclusion: This study highlights the growing acceptance of modern technologies in psychiatric care, with patients showing increased readiness to use telepsychiatry and mobile health self-management tools, in particular mobile applications, after the COVID-19 pandemic. This was triggered by the pandemic, but continues despite its expiry. In the face of patient readiness, the key issue now is to ensure the safety and efficacy of these tools, along with providing clear guidelines for clinicians. It is also necessary to draw the attention of health systems to the widespread implementation of these technologies to improve the care of patients with mental disorders.

KEYWORDS

mHealth, mobile health, telehealth, digital health, smartphone, APP, acceptance, expectation

1 Introduction

Mobile Health (mHealth) is a rapidly developing field that leverages the capabilities of mobile devices, including smartphones, patient monitoring tools, personal digital assistants (PDAs), and various wireless devices, to enhance healthcare (1). In recent years, the field of mobile health has seen significant growth and change, both in prevalence and the features provided. The widespread availability of the internet and smartphones, offering mobile applications, have been driving this trend. Mobile Health solutions have already been implemented for a few years in the field of psychiatry and first experiences show that they can be a valuable element to complement the coordinated and personalized care. These solutions can support the diagnostics, patient education, therapeutic process, as well as self-management in illness (2). Especially, they can also be very helpful in monitoring chronic, recurrent mental disorders on a continuous, real-time basis (3–7). There is also a great potential for improving communication with specialist (3–7). Remote communication via text message, telephone, video call or chat, known as telemedicine, has been known for a long time. It was a good option for patients with limited access to health care facilities. In the face of the pandemic, most patients confronted the problem of not being able to consult a specialist as before. This has resulted in an explosive demand for remote contact, causing telepsychiatry to develop in a literally revolutionary way. Remote solutions might make it easier to contact health care professionals also during emergencies, health crises and suicide threats.

Smartphones and mobile applications, due to their increasing availability, low price, and simple functionality, can be excellent tools to support people with mental health problems. Nevertheless, a key factor influencing the use of these solutions in psychiatric care is patients perception. The results of studies analyzing the opinions of patients participating in clinical trials using m-health devices are highly inconsistent. Studies conducted among patients with bipolar disorder (BD) and schizophrenia indicated high level of satisfaction and acceptance of the tested interventions (8, 9). Similarly, an app dedicated to preventing self-aggressive behaviors among youth was also highly rated (10). It is worth nothing, however, that these studies focused on patients in a relatively stable mental state and lasted for a short time, up to a few months. Clinical observations, on the other hand, suggest that interest in a given tool decreased with longer use. In one study, the interest in long-term use of wearables with built-in sensors among BD patients was examined. The results revealed that patients were not keen on using these tools over an extended period, even though the same patients reported high satisfaction and acceptance of the tool in a three-month study (11). Walsh et al. conducted a review of patients' opinions using mHealth tools for monitoring mental states. An analysis of 57 papers showed that patients were generally content with their usage, but the proposed solutions did not entirely meet their expectations (12). Patients pointed out the need for more personalized and flexible approaches that align with their preferences and needs, are user-friendly, and genuinely helpful. Negative aspects of mHealth tools were also highlighted, such as the annoying and stressful continuous reminders of their illness, a feeling of being monitored, loss of dignity, and autonomy (12–14). In a Polish study evaluating the feasibility of monitoring the mental state of patients with BD and predicting mood phase changes using a dedicated mobile application (ChADMon), a high dropout rate (44%) was observed at one-year follow-up (15). However, to date, no study has assessed attitudes, concerns, and expectations toward mHealth solutions in psychiatry in the Polish population.

The studies cited are from before the pandemic. The COVID-19 pandemic has served as a significant stimulus for the development of mental mobile healthcare, due to disruption of conventional doctor-patient interactions. In particular, over the course of pandemic, there was a notable growth in the adoption of telepsychiatry in comparison to previous years (16, 17). This trend correlated with concomitant mental deterioration and increased psychiatric symptoms in the population during the pandemic (18–20). The pandemic certainly forced a rapid transformation of contact with specialist through remote system. Therefore, it is interesting to explore how this form of contact was evaluated by patients during the peak of the pandemic, and how this is shaping up after the pandemic expires and the possibility of returning to the traditional form of contact. Due to the difficulty in contacting a specialist, many patients had to cope on their own during the most critical period. Regardless of telepsychiatry, there was a rapid growth of the mobile app market during this period as an

attempt to respond to increased medical needs. However, it has not been studied how the pandemic period affected the use of and attitudes toward the tools offered by mobile health. In particular, it is interesting to explore how this has affected two of the most prominent areas of mHealth in psychiatry, namely telepsychiatry and mHealth self-management tools for mental health support. Therefore we decided to explore how perceptions among patients of these solutions were shaped at the beginning of the pandemic—where change was forced, through its peak, to its extinction and the associated possibility of a return to traditional forms of treatment. This can provide valuable information on the further development of mHealth in psychiatry.

The purpose of this study was to assess the prevalence, attitudes, preferences and concerns about telepsychiatry and mHealth self-management tools, among patients with mental disorders over the period 2020–2023, i.e., at the onset, peak and after the expiration of the COVID-19 pandemic. The specific aims of this study were: (1) to assess the prevalence and usage of mobile devices and mHealth solutions and evaluate changes in this field between 2020 and 2023; (2) to assess attitudes, expectations, and preferences toward telepsychiatry and mHealth self-management tools in psychiatry, and to evaluate changes in this field between 2020 and 2023; (3) to assess concerns and risks associated with telepsychiatry and mHealth self-management tools in psychiatry and evaluate changes in this field between 2020 and 2023.

2 Materials and methods

A semi-structured, a 28-item questionnaire was developed (see Supplementary material), taking into consideration existing literature, insights into specific aspects of mental disorders, and knowledge from clinicians at the Institute of Psychiatry and Neurology. These clinicians had prior experience in conducting Polish research involving mHealth app in the field of psychiatry. The questions aimed to explore the characteristics of mHealth solutions, including telepsychiatry and mobile apps that would be acceptable for long-term use from a patients' perspective. We sought to assess patients' needs, expectations, and potential applications of mobile technologies in managing their mental health.

At the forefront of the questionnaires, there is brief information about the purpose of the survey. This is followed by research questions, both closed and open, covering the following three main areas:

1. the prevalence of mobile device and internet usage and patients' current experiences with the use of mHealth solutions in the area of health and mental health (what percentage of respondents already have some experience, how they evaluate the tested solutions);
2. patients' attitudes, opinions, and preferences regarding mHealth solutions in psychiatry, in particular views regarding telepsychiatry and self-management tools. The questions relate to interest in the use of mobile technology in psychiatry, the opportunities that it can offer, the level of readiness to use it, factors influencing patients' attitudes (including physician/psychologist influence), needs, expectations and areas of application of mHealth technology from the patient's perspective, preferences for the selection of specific self-management tools, and preferences for specific functions of mobile apps;
3. concerns and risks associated with the adoption of mHealth solutions for mental health management.

Additionally, the questionnaire concluded with clinical and demographic data collection. Data is collected on age, gender, place of residence, education, occupational status. The questionnaire also includes a section on the respondent's health (a checkbox for the type of mental disorder the respondent suffers from) and a Patient Global Impression (PGI) scale, on which the respondent assesses his or her general health on a scale of 1–7 points.

The online survey was administered to individuals seeking mental health support who willingly participated in the study. Distribution involved reaching out to individuals receiving care within mental health facilities and counseling centers across 16 regions (voivodeships) in Poland. The distribution process spanned from May 2020 to the end of May 2023 on a continuous basis, resulting in the participation of 354 patients, representing a response rate of 84%. The specific inclusion criteria for participants were as follows: (1) diagnosis of any mental disorder; (2) residence in Poland; (3) age 18 or older; (4) consent to participate in the survey.

The study adhered to ethical guidelines and was communicated to the Bioethics Committee at the Institute of Psychiatry and Neurology in Warsaw, Poland. Formal approval from the Bioethics Committee was deemed unnecessary since the survey posed no threat to the participants' well-being and interests. Data were handled with utmost confidentiality, fairness, and equality, in accordance with the Helsinki principles.

To meet the survey's aim 1, we conducted a summative analysis of responses regarding the prevalence and usage of mobile devices and mHealth solutions from 2020 to 2023, and then compared the obtained responses between the years 2020–2023 using the Chi-square test. If the difference was statistically significant, we conducted additional comparisons for each year considering the Bonferroni correction. To address aim 2 of the study, we conducted a summative analysis of responses regarding the attitudes, expectations, and preferences toward telepsychiatry and mHealth self-management tools in psychiatry and then compared the obtained responses between the years 2020–2023 using the Chi-square test for nominal-scale variables. If the difference was statistically significant, we conducted additional comparisons for each year considering the Bonferroni correction. Kruskal-Wallis ANOVA was used for ordinal-scale variables with non-normal distributions. In addition, a qualitative analysis of open-ended questions was conducted. To address aim 3 of the study, we conducted a summative analysis of responses regarding the concerns and risks associated with the telepsychiatry and mHealth self-management tools in psychiatry and then compared the obtained responses between the years 2020–2023 using the Chi-square test. If the difference was statistically significant, we conducted additional comparisons for each year considering the Bonferroni correction. In addition, a qualitative analysis of open-ended questions regarding patients' concerns was conducted.

Statistical analysis was conducted using Statistica 13.3 software. Descriptive statistics included means, standard deviations, medians, and interquartile ranges for data that did not meet normal distribution criteria. Chi-square tests were applied for nominal-scale variables,

TABLE 1 General characteristics of the respondents ($n = 354$).

Variables		Year ($n = 354$)			
		2020 ($n = 78$)	2021 ($n = 70$)	2022 ($n = 88$)	2023 ($n = 118$)
Sex	Female	60.3% ($n = 47$)	60% ($n = 42$)	63.6% ($n = 56$)	54.2% ($n = 64$)
	Male	39.7% ($n = 31$)	40% ($n = 28$)	36.4% ($n = 32$)	45.8% ($n = 54$)
Age	18–24	10.2% ($n = 8$)	5.7% ($n = 4$)	2.3% ($n = 2$)	5.9% ($n = 7$)
	25–39	37.2% ($n = 29$)	22.9% ($n = 16$)	34.1% ($n = 30$)	32.2% ($n = 38$)
	40–55	33.3% ($n = 26$)	42.8% ($n = 30$)	47.7% ($n = 42$)	47.5% ($n = 56$)
	55–64	16.7% ($n = 13$)	20% ($n = 14$)	12.5% ($n = 11$)	11.9% ($n = 14$)
	>65	2.6% ($n = 2$)	8.6% (n = 6)	3.4% ($n = 3$)	2.5% ($n = 3$)
Education	Lower secondary	16.7% ($n = 13$)	22.9% ($n = 16$)	23.9% ($n = 21$)	28.8% ($n = 34$)
	Professional	14.1 ($n = 11$)	21.4% ($n = 15$)	17% ($n = 15$)	10.2% ($n = 12$)
	Higher	69.2% ($n = 54$)	55.7% ($n = 39$)	59.1% ($n = 52$)	61% ($n = 72$)
Professional activity	Student	11.5% ($n = 9$)	4.3% ($n = 3$)	2.3% ($n = 2$)	4.2% ($n = 5$)
	Working	82.1% ($n = 64$)	71.4% ($n = 50$)	71.6% ($n = 63$)	89.8% ($n = 106$)
	Pensioner	6.4% ($n = 5$)	15.7% ($n = 11$)	6.8% ($n = 6$)	5.1% ($n = 6$)
	Other	0% ($n = 0$)	8.6% ($n = 6$)	19.3% ($n = 17$)	0.9% ($n = 1$)
Residence	City > 250,000	53.9% ($n = 42$)	44.3% ($n = 31$)	46.6% ($n = 41$)	56% ($n = 66$)
	City 50,000–250,000	17.9% ($n = 14$)	24.3% ($n = 17$)	27.3% ($n = 24$)	22% ($n = 26$)
	City < 50,000	20.5% ($n = 16$)	17.1% ($n = 12$)	20.4% ($n = 18$)	17.8 ($n = 21$)
	Village	7.7% ($n = 6$)	14.3% ($n = 10$)	5.7% ($n = 5$)	4.2% ($n = 5$)

TABLE 2 Health information of the respondents ($n = 354$).

Variables		Percent (number)
"I am treated for…"	Depression	63% ($n = 223$)
	Anxiety	20.3% ($n = 72$)
	Sleep disorders	14.4% ($n = 51$)
	Addictions	12.4% ($n = 44$)
	Bipolar disorder	10.2% ($n = 36$)
	Neurosis	2% ($n = 7$)
	Schizophrenia	1.4% ($n = 5$)
	Other	2.8% ($n = 10$)
"At present, I feel…"	Very seriously ill	0.3% ($n = 1$)
	Seriously ill	1.1% ($n = 4$)
	Noticeably ill	7.1% ($n = 25$)
	Moderately ill	33.6% ($n = 119$)
	Slightly ill	26.3% ($n = 93$)
	Almost healthy	27.1% ($n = 96$)
	Healthy	4.5% ($n = 16$)

while Kruskal-Wallis ANOVA was used for ordinal-scale variables with non-normal distributions. In instances of small group sizes, the chi-square test aggregated lower-ranked responses, ensuring result interpretability. For post-hoc comparisons, the Bonferroni correction was employed to enhance the test's reliability. Relationships between variables were assessed through regression and correlation methods, exploring the impact of demographic factors on the responses. Statistical significance was determined at $p < 0.05$.

3 Results

3.1 General characteristics

A total of 354 respondents completed the online survey ($n = 354$). All closed questions were completed by respondents (100%). The general characteristics of patients are presented in Table 1. The information about the health of respondents is presented in Table 2.

3.2 Prevalence and usage of mobile devices and mHealth solutions—results for aim 1

3.2.1 Prevalence and usage of mobile devices and mHealth solutions—aggregate analysis (2020–2023)

A significant number of respondents declared that they use mobile devices at least once a week (92.7%). Thirty-two percent use remote contact with a specialist frequently (once a week to once a month), while 67.2% use it only once a year or less often. Forty-two percent of patients stated that they have heard about mHealth tools (such as apps, smart watches, wristbands etc.), or already used them. Simultaneously, 52.3% of respondents had heard little or nothing about it. The exact distribution of responses to questions related to the prevalence and usage of new technologies is presented in Figure 1.

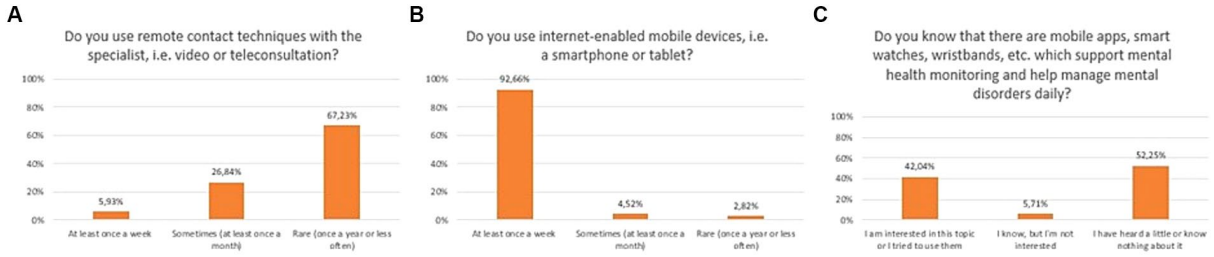

FIGURE 1
Responses regarding prevalence and usage of mobile devices and mHealth solutions among mental health patients; **(A)** Usage of remote techniques to communicate with specialists; **(B)** Usage of mobile devices; **(C)** Awareness of mHealth tools dedicated to mental health patients.

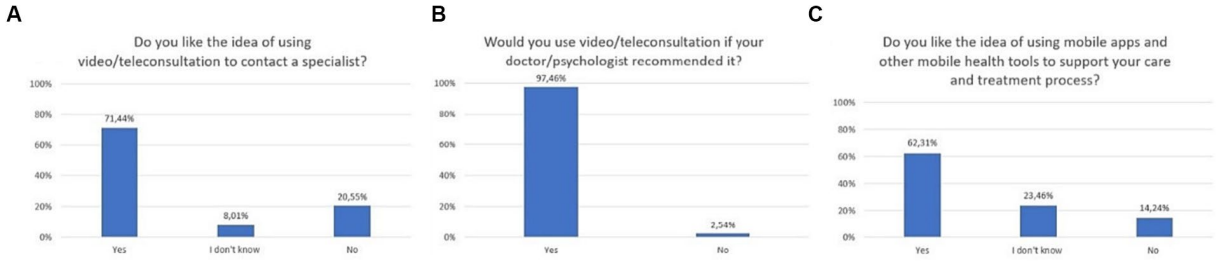

FIGURE 2
Responses regarding attitudes, expectations, and preferences; **(A)** Attitudes toward video/teleconsultation; **(B)** Readiness to use video/teleconsultation upon recommendation by a doctor/psychologist; **(C)** Attitudes toward mHealth tools.

3.2.2 Changes in prevalence and usage of mobile devices and mHealth solutions between 2020 and 2023

Prevalence of using remote contact techniques with mental health specialist between 2020 and 2023 did not change statistically significantly ($Chi^2 = 7{,}621{,}773$, df = 3, $p = 0.05451$). Similarly, awareness of mHealth tools in psychiatry between 2020 and 2023 did not change statistically significantly ($Chi^2 = 6{,}731{,}831$, df = 3, $p = 0.08095$).

3.3 Attitudes, expectations, and preferences toward telepsychiatry and mHealth self-management tools in psychiatry—results for aim 2

3.3.1 Attitudes, expectations, and preferences toward telepsychiatry and mHealth self-management tools in psychiatry—aggregate analysis (2020–2023)

The majority of respondents liked the idea of using video/teleconsultation to contact a specialist (71.4%), and as much as 97.5% would use them if that was the recommendation of the specialist. Sixty-two percent of respondents liked the idea of using mobile apps and other mobile health tools to support care and treatment process (Figure 2). In a multiple-choice question, the majority of respondents declared that telepsychiatry could be applied as a complementary tool, used to continue treatment (74.6%). According to 29.1%, remote contact could be applicable from the first visit (Figure 3). As much as 40.7% of respondents stated that they would like video/teleconsultations to account for more than 50% of all visits. 96.6% of respondents would use a mental health mobile app if that was the recommendation of the specialist. The exact distribution of responses to main questions related to attitudes toward video/teleconsultations is shown in Figures 2, 3.

The great majority of respondents declared that mental health mobile apps could be useful for patients through the following features: educational (95.8%), self-motivating (93.8%), self-monitoring of well-being with visualization of this date (94.9%), monitoring activity to detect early signs of deterioration (78.8%), therapy support—relaxation module (94.7%), therapy support—medications reminders (94.7%), therapy support—allowing on-going communication with the doctor/psychologist (95.5%). Responses to an open-ended question about other useful features did not contain any indications other than the above.

3.3.2 Changes in attitudes, expectations, and preferences toward telepsychiatry and mHealth self-management tools between 2020 and 2023

A statistically significant difference was found between 2020 and 2023 regarding attitudes toward video/teleconsultation ($Chi^2 = 62{,}60{,}504$, df = 6, $p = 0.00000$). The Bonferroni correction was included in the comparisons for each year (statistically significance: 2020 vs. 2022: $Chi^2 = 21{,}41{,}480$, df = 2, $p = 0.00002$; 2020 vs. 2023: $Chi^2 = 45{,}61{,}123$, df = 2, $p = 0.00000$; 2021 vs. 2022: $Chi^2 = 10{,}50{,}707$, df = 2, $p = 0.00523$; 2021 vs. 2023:$Chi^2 = 27{,}36{,}393$, df = 2, $p = 0.00000$). The trend is presented in Figure 4. A statistically significant difference was also found between 2020 and 2023 regarding attitudes toward mHealth tools ($Chi^2 = 14{,}70{,}202$,

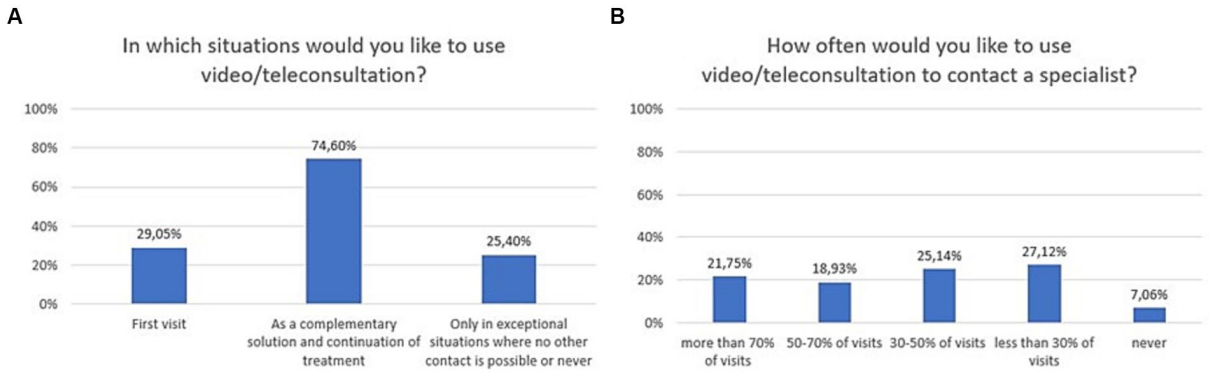

FIGURE 3
Responses regarding attitudes, expectations, and preferences; **(A)** Situations in which respondents would like to use video/teleconsultations (multiple-choice question); **(B)** Expected frequency of video/teleconsultation.

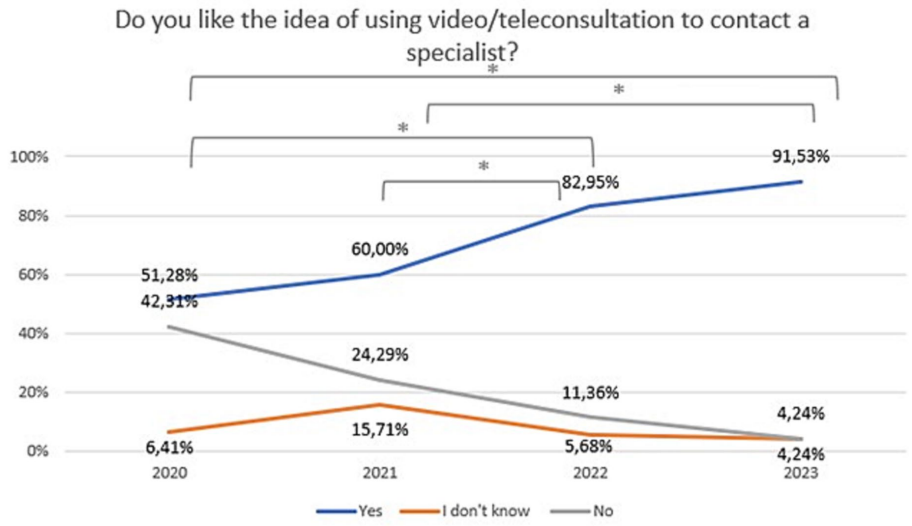

FIGURE 4
Responses regarding idea of using video/teleconsultation over the period 2020–2023. *Statistically significant difference.

df = 6, $p = 0.02271$). The Bonferroni correction was included in the comparisons for each year (statistically significance: 2021 vs. 2022: $Chi^2 = 9{,}924{,}326$, df = 2, $p = 0.00700$; 2021 vs. 2023: $Chi^2 = 9{,}550{,}167$, df = 2, $p = 0.00844$). The trend is presented in Figure 5. The percentage of mental health patients, who declared they were ready to use new technologies between 2020 and 2023 is presented in Figure 6 ($Chi^2 = 15{,}93{,}151$, df = 3, $p = 0.00117$; statistically significance: 2020 vs. 2023: $Chi^2 = 8{,}381{,}067$, df = 1, $p = 0.00379$; 2021 vs. 2023: $Chi^2 = 14{,}26{,}987$, df = 1, $p = 0.00016$; 2022 vs. 2023: $Chi^2 = 7{,}254{,}401$, df = 1, $p = 0.00707$; Figure 6).

Changes in the declared intention to use video/teleconsultation frequency are shown in Figure 7. The variable was tested on an ordinal scale and the Kruskalla-Wallis ANOVA test showed statistical significance ($H = 95.12151$, $p = 0.000$). Over the period 2020–2023, there was an increase in the preference for the use of video/teleconsultation from 47.4% in 2020 to 95.8% in 2023. Relevant responses were combined to ensure that the size of the test group was appropriate ($Chi^2 = 79{,}53{,}916$, df = 3, $p = 0.00000$; statistically significance: 2020 vs. 2022: $Chi^2 = 37{,}56{,}181$, df = 1, $p = 0.00000$; 2020 vs. 2023: $Chi^2 = 61{,}06044$, df = 1, $p = 0.00000$; 2021 vs. 2022: $Chi^2 = 16{,}72{,}400$, df = 1, $p = 0.00004$; 2021 vs. 2023: $Chi^2 = 32{,}45{,}982$, df = 1, $p = 0.00000$; Figure 8).

3.3.3 Attitudes, expectations and preferences toward telepsychiatry and mHealth self-management tools—analysis of open-ended questions (2020–2023)

In response to why patients like the idea of video/teleconsultation as a tool to contact a specialist, the majority mentioned to convenience and simplicity of such a solution ($n = 38$). In addition, respondents pointed to time-saving ($n = 36$), the only possible form of contact during the pandemic ($n = 47$), the feeling of security ($n = 56$), and fast contact ($n = 32$). One person each indicated the possibility of constant contact, access to better specialists, and the assurance of anonymity in small towns. Among the respondents who did not like this idea, they mentioned that it will not replace live contact ($n = 18$), that they prefer traditional contact ($n = 29$), and they fear being recorded/overheard ($n = 48$). One person each indicated the difficulty of establishing a

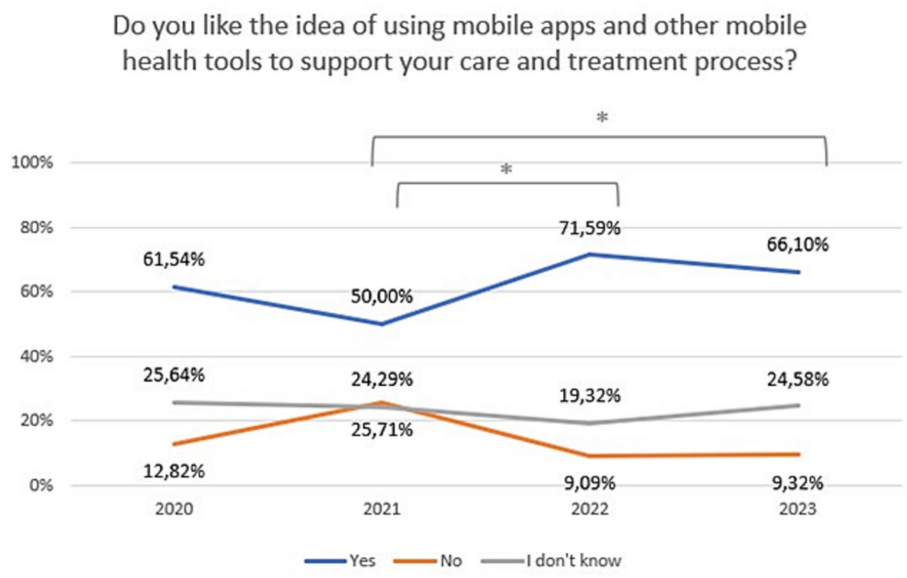

FIGURE 5
Responses regarding idea of using mobile technology over the period 2020–2023. *Statistically significant difference.

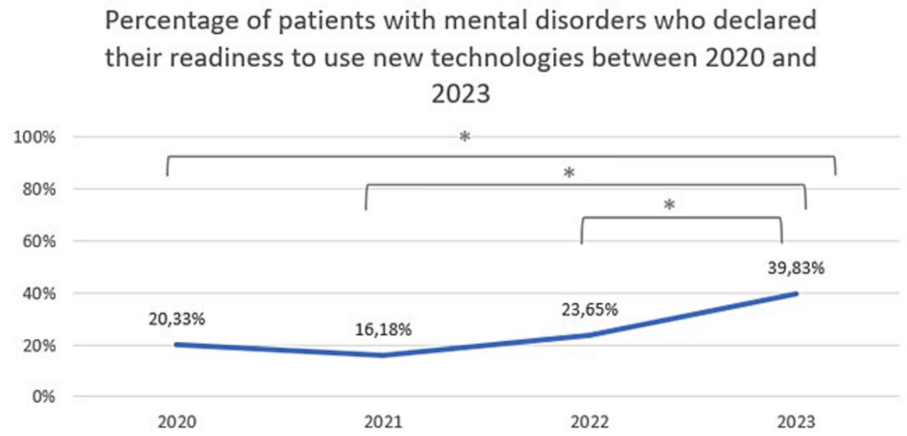

FIGURE 6
The percentage of patients with mental disorders who declared they were ready to use new technologies between 2020 and 2023. *Statistically significant difference.

relationship, the uncomfortable feeling, the inability to talk quietly at home, and that it is convenient for doctors, not patients.

The majority of respondents who answered the question what they would like to improve indicated the quality and stability of the connection ($n=52$), the ability to connect by video, as talking alone is insufficient ($n=18$), security and privacy ($n=55$), more personalized solutions ($n=45$). One person each pointed to the possibility of remanding by SMS, compatibility on various devices, and ability to send files.

Patients gave a variety of responses as to why they liked the idea of using mobile technology, such as additional help in managing disease daily ($n=43$), opportunity for additional interaction with the health service/medical doctor ($n=53$), convenience ($n=56$), mobilization and reminder ($n=31$), assistance in the treatment process ($n=43$). Among those who did not like this idea, respondents mentioned that they have no experience with such solutions ($n=18$), see them as entertainment, or gadgets ($n=12$), are afraid of privacy ($n=52$), and would not be able to use them ($n=5$).

3.4 Concerns and risks toward telepsychiatry and mHealth self-management tools in psychiatry—results for aim 3

3.4.1 Concerns and risks associated with the use of telepsychiatry and mHealth self-management tools in psychiatry—aggregate analysis (2020–2023)

Slightly less than half of respondents (47.6%) had some concerns about the use of video/teleconsultation, while only 28% had concerns

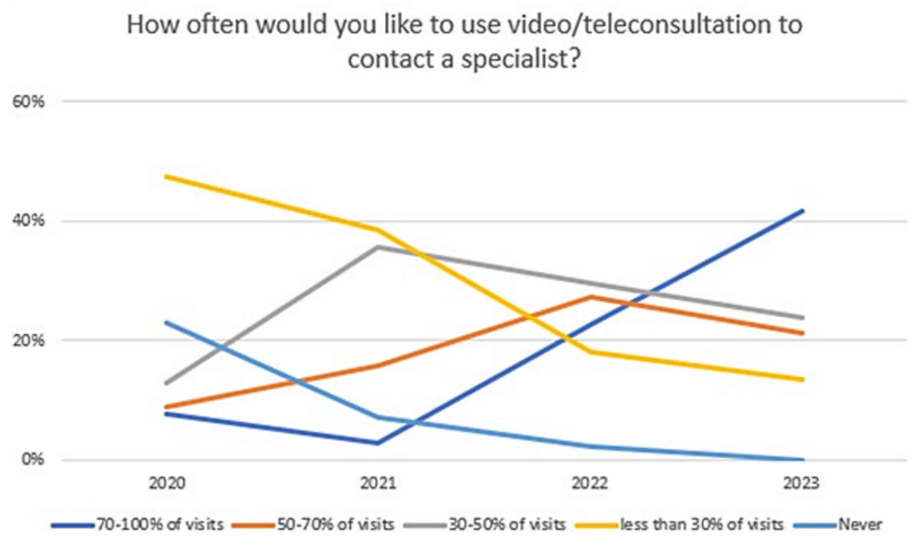

FIGURE 7
Responses regarding the declared desire for frequency of use video/teleconsultation over the period 2020–2023.

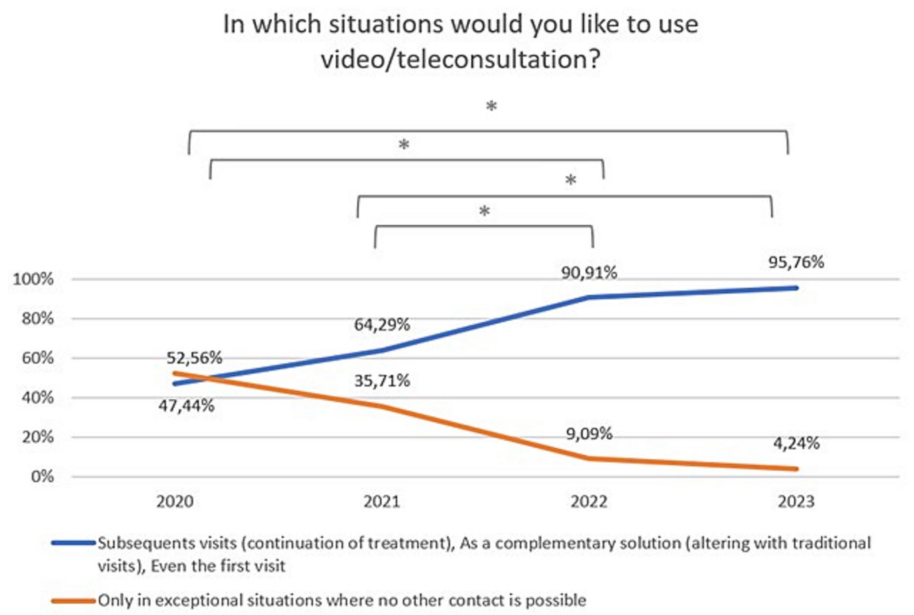

FIGURE 8
Responses regarding the desire to use video/teleconsultation in specific situations over the period 2020–2023. *Statistically significant difference.

about the use of mobile apps and other mHealth tools to support care and treatment. The exact distribution of responses to questions related to concerns over the use of new technologies is shown in Figure 9.

3.4.2 Change in perceived concerns and risks associated with the use of telepsychiatry and mHealth self-management tools in psychiatry between 2020 and 2023

Concerns about video/teleconsultation in psychiatry between 2020 and 2023 are shown in Figure 10 ($Chi^2 = 19{,}23{,}567$, df = 6, p = 0.00378). The Bonferroni correction was included in the comparisons for each year (statistically significance: 2020 vs. 2023: $Chi^2 = 10{,}36{,}361$, df = 2, $p = 0.00562$; 2021 vs. 2023: $Chi^2 = 11{,}33{,}167$, df = 2, $p = 0.00346$). Concerns toward mHealth tools in psychiatry between 2020 and 2023 are shown in Figure 10 ($Chi^2 = 10{,}44{,}849$, df = 6, p = 0.10699).

3.4.3 Concerns and risks associated with the use of telepsychiatry and mHealth self-management tools-analysis of open-ended questions (2020–2023)

Among the concerns about video/teleconsultations in the open questions, respondents mentioned: privacy and security ($n = 56$), lack

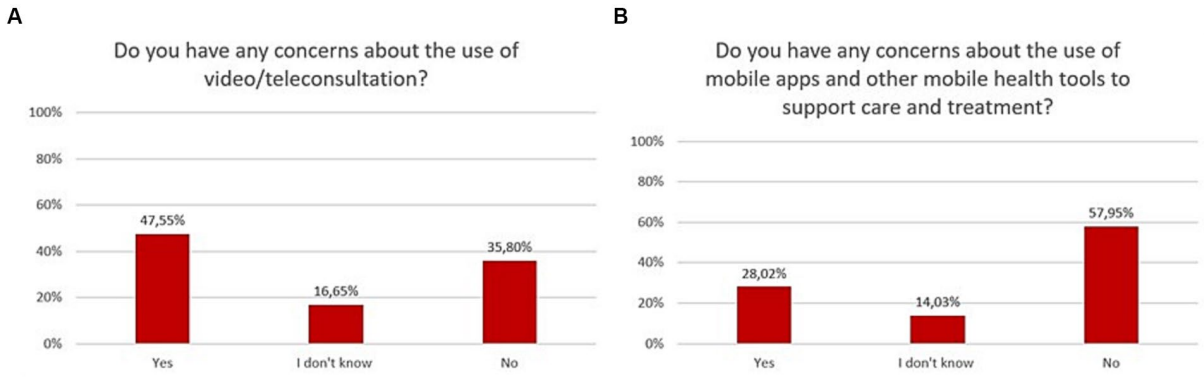

FIGURE 9
Responses regarding concerns and risks associated with the use of mHealth in psychiatry; **(A)** video/teleconsultation concerns; **(B)** mHealth tools concerns.

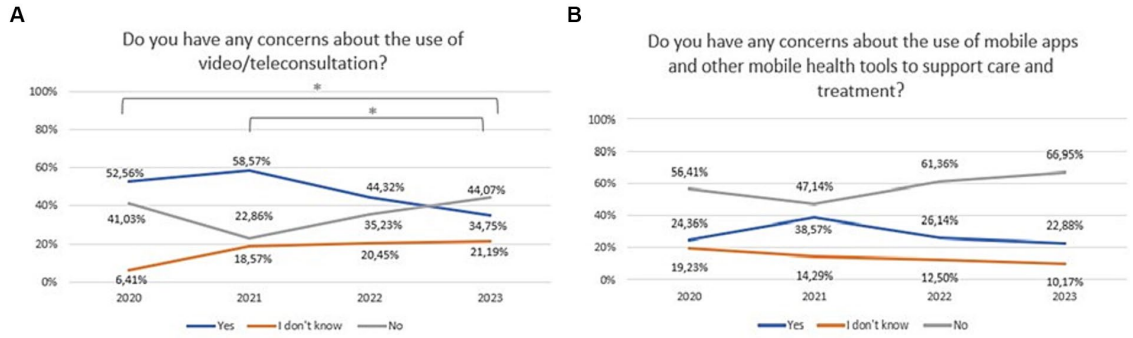

FIGURE 10
Responses regarding concerns about: **(A)** the use of video/teleconsultation over the period 2020–2023; **(B)** the use of mobile apps and other mobile health tools to support care and treatment over the period 2020–2023. *Statistically significant difference.

of comfort in conversation ($n = 31$), inability to talk to a medical doctor live ($n = 14$), superficial visits ($n = 32$), medical mistakes ($n = 4$), devices support ($n = 2$).

Among the concerns about mobile tools in the open questions, respondents mentioned: privacy and security ($n = 51$), uncertainty about the effectiveness of these tools ($n = 31$), lack of reliable data on clinical usefulness ($n = 20$), clinicians' hesitancy to recommend these tools ($n = 14$), and low-tech level ($n = 8$), lack of experience with a reliable solution ($n = 4$). One patient pointed out that such solutions may harm patients ($n = 1$).

3.5 Influence of age, sex, education, professional activity, place of residence, and health status on readiness to use new technologies

The Kruskal-Wallis test showed no statistically significant differences in readiness to use new technologies between groups depending on age ($H = 4$; $p = 0.24$), education ($H = 2$; $p = 0.53$), professional activity ($H = 6$, $p = 0.43$), place of residence ($H = 3$, $p = 0.05$), and health status ($H = 6$; $p = 0.14$). The U-Mann–Whitney test showed no statistically significant differences in readiness to use new technologies between groups depending on sex ($U = 14{,}217{,}00$, $p = 0.32$).

4 Discussion

The challenges, that the 21st century has brought, include mental health problems, which are now major contributors to the global burden of disease (21). Unfortunately, most people in need of psychiatric treatment are not getting the help. Above all, high costs and a shortage of clinicians stand in the way. Negative social attitudes toward psychiatric treatment and perceived stigma may also contribute. It is estimated that the treatment gap for people with mental disorders is as high as 50% on average worldwide (22). In countries with high income, this percentage is obviously lower, but the limitation in accessibility is still present due to other factors. Common barriers to seeking treatment include lack of time, transport issues or availability of professionals in the patient's area. However, the 21st century has also brought new options for dealing with mental disorders. Mobile health has begun to play a role in modern psychiatric care. The health system is increasingly embracing new digital solutions such as telepsychiatry. This helps to make mental health care more accessible, but also opens up entirely new

possibilities, such as mobile applications to support diagnosis, monitoring and treatment. Some of these solutions are already in place and some, such as telepsychiatry, have become routine clinical practice since the COVID-19 pandemic. This implementation, however, is taking place at different rates in countries worldwide, often at suboptimal levels (23). This is also the case in Poland. No significant impact has yet been made on mainstream mental health care, despite the many solutions that are available. One obstacle here may be the targeted users' knowledge of and attitudes toward mobile health solutions. Therefore, in this study we aimed at assessing the prevalence, attitudes and concerns regarding new technologies in mental health care, specifically, about telepsychiatry and mHealth self-management tools, among individuals with mental disorders.

The first optimistic finding is that significant number of respondents declared that they use mobile devices at least once a week (93%). This already shows that the vast majority of people with mental disorders own and use mobile devices with internet access. Second, that readiness to use new technologies among patients increased from 20% in 2020 to 40% in 2023. Moreover, their willingness to use new technological solutions in psychiatry has also increased significantly over the last 3 years, and currently one in two to three patients would like to be supported in this way. In particular, there was a significant increase in the preference for the use of telepsychiatry (video or teleconsultation) from 47% in 2020 to as much as 96% in 2023. Importantly, 97.5% would have used them if they had been recommended by a specialist. However, in terms of personal experience, on average only 32% of patients with mental disorders used telepsychiatry quite often (between once a week and once a month) between 2020 and 2023. This may indicate that the needs and expectations of patients are greater than the provision of these services. Telepsychiatry undoubtedly has many benefits that are perceived by patients with mental disorders. It certainly increases patients' access to professional psychiatric help by making them independent of their location and mobility. In addition, patients may feel more comfortable during an online visits in the comfort of their own home than in a face-to-face meeting. Other advantages pointed out by patients in our survey were as follows: simplicity of such solutions, time-saving, or fast and constant contact with specialists. Concluding, with the emergence of the pandemic, the last 3 years have been a revolution in the development of telepsychiatry. Patients, though initially coerced, are now mostly convinced of its advantages. In 2023, although the pandemic has subsided, the preference for using remote contact with a specialist persists.

Given that such services are as effective as traditional visits in treating depression and improving quality of life (24), the creation of a well-organized system of telepsychiatry appears to be an opportunity for many previously untreated patients. This also applies to the therapeutic process. A recent systematic review showed that video-consultation-based psychotherapy is as effective as traditional visits in reducing symptoms of depression (25). However, patients also had some concerns about telepsychiatry. These were expressed by as many as 53% of patients in 2020, but this percentage dropped significantly to 35% in 2023. These include fear of being overheard or recorded, concerns about losing contact with a known model such as face-to-face consultation, the problem of establishing a relationship, or the issues of confidentiality and privacy during the connection.

As regards the mHealth self-management tools (such as mobile apps, smartwatches and wristbands), the level of interest and willingness to use was similar to that of telepsychiatry. More than 60% of patients with mental disorders liked the idea of using mobile apps and other mobile health tools to support their care and treatment process. This percentage also increased during the pandemic, reaching 66% in 2023. As to personal experiences, 42% of patients stated that they have heard about self-management tools (such as apps, smart watches, wristbands, etc.), or already used them.

In general, these findings are consistent with those currently available in the literature (26, 27). Patients with mental disorders are ready, open and willing to use the solutions offered by new technologies. Therefore, this factor does not seem to be an obstacle to their wider use. However, 28% of patients expressed some concerns about the use of mHealth tools, it is worth quoting them here, as they seem very well founded and decide on their broader use. Respondents indicated that have concerns about the reliability of these tools and the security of their confidential data. They are also uncertain about the effectiveness of these tools and do not have a clear recommendation from their specialist.

It seems that, the concern is above all about mobile applications that do not meet sufficient clinical validation standards. In the face of the COVID-19 pandemic, there was a surge in the number of apps based on artificial intelligence, marketed as mental health support tools. However, they often failed to meet their stated objectives and even posed real risks to the user (28–30). However, this has laid the foundations for their growing use in supporting mental health. Although there are now thousands of English-language apps related to mental health, only the Headspace and Calm app have any clinical studies indicating effectiveness and safety. At the same time, they rank highest in terms of number of downloads and user activity (31). Despite the mixed findings, for such apps, recommendations tend toward recommending them. Given the low cost and potential accessibility to a wide range of people who would otherwise not have access to support and treatment.

When it comes to implementing a regulatory framework aimed at health apps and their market access, Germany has taken a pioneering role. DiGA (Digitale Gesundheitsanwendungen, in German meaning digital health apps) (32). If an app can prove both compliance with the general requirements and positive clinical effects, the German Federal Agency for Medicines and Health Products approves it and it is reimbursed by insurance. Similar models have been developed in France and Belgium (33). Other European countries, including Poland, have so far chosen approaches with legal obligations and compliance rules based on the General Data Protection Regulation or the Medical Devices Regulation (34, 35).

However, there appears to be a need for specific guidelines in particular countries. Collaboration with World Psychiatric Associations (WPA) member societies will also contribute to the development of evidence-based guidelines for the safe and ethical use of digital mental health tools in countries around the world. This will allow to use the potential of mHealth in the best way and give a broad range of people access to cheap, effective and safe tools to help improve their mental health.

The number of positive attitudes toward telepsychiatry and mHealth self-management tools increased between 2020 and 2023, as we noted earlier. However, one of the interesting findings of our study was that no differences regarding attitudes were found between 2020 and 2021 when COVID-19's effects were the most severe. Several

factors could have contributed to this. In the first place, the effects of the pandemic varied by region over time, thereby affecting the overall statistical significance. Second, the COVID-19 pandemic also had some delayed effects, among which appear to be improved attitudes toward telepsychiatry and mHealth tools. In addition, other external factors, such as the popularity of mobile solutions on an annual basis, are also contributing to this rise.

The results of this survey show that it is not patient attitudes that stand in the way in the wider use of mHealth solutions. With all certainty, it is worth taking advantage of the readiness of people with mental disorders to use mHealth tools. However, one cannot forget about the issues of verifying the effectiveness of these tools and their security, including the security of sensitive data. The lack of clear recommendations for specific tools can also be a problem for clinicians who are not sure which solutions to recommend to patients (28). This may be another reason for the low implementation of new technologies in psychiatry in Poland and worldwide.

This study has certain limitations, that should be acknowledged. Firstly, respondents that chose to participate in the study might be predisposed to a positive attitudes toward telepsychiatry and mHealth and thereby introduce a positive bias. However, the response rate was high which suggest a reliable sample. Secondly, it cannot be assumed that the respondents' declared interest in mHealth will translate into actual use. Further efforts are needed to help implement these solutions. Thirdly, most data assessed were from patients living in urban areas. Finally, cross-sectional design and self-reported data were also limitations of this study. Therefore, the results should be generalized with particular care.

5 Conclusion

In this study, we explored the prevalence, attitudes, preferences and concerns about mobile health, including telepsychiatry and self-management tools among patients with mental disorders over the pandemic period from 2020 to 2023. The survey revealed that patients with mental disorders are increasingly embracing mobile technologies, such as telepsychiatry and self-management tools (mainly mobile applications) to support their treatment. The vast majority (up to 95% of patients with mental disorders) use mobile devices at least once a week. Over the 3 years of the pandemic (from 2020 to 2023), the proportion of patients willing to use mobile solutions increased. In particular, there was a remarkable increase in preference among patients for using telepsychiatry—in 2023 the percentage of respondents choosing this form of contact with a specialist was as high as 96%. Similarly, mHealth self-management tools were of high interest to patients. More than 60% of patients like the idea of using mobile apps and other mobile health tools to support the care and treatment process. This percentage also increased during the pandemic, reaching 66% in 2023. At the same time, the percentage of patients who have concerns about using mHealth solutions decreased. However, in 2023, 35% and 28% of patients still have concerns about telepsychiatry and the reliability and safety of m-health self-management tools, respectively.

Summarizing the results of the survey, there is a clear trend of increasing acceptance of mHealth solutions, along with increasing patient readiness to utilize them. This was triggered by the pandemic, but continues despite its expiry.

The results suggest that there is considerable potential to improve the accessibility and effectiveness of psychiatric care using mHealth technologies. However, caution must be exercised regarding the safety and effectiveness of these tools. This requires, among other things, guidelines for clinicians to recommend safe and effective solutions to patients. In order to meet the growing readiness and expectations of patients and to contribute to the improvement of psychiatric care, the implementation of mHealth solutions in Poland and worldwide requires the urgent attention of health system decision-makers.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MD: Conceptualization, Data curation, Formal analysis, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. AG: Formal analysis, Visualization, Writing – original draft, Writing – review & editing. AA: Funding acquisition, Supervision, Writing – review & editing. PM: Conceptualization, Project administration, Supervision, Writing – review & editing.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2023.1322695/full#supplementary-material

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Prevalence and correlates of suicidal ideation in the general public during the fifth wave of COVID-19 pandemic in Hong Kong

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Introduction: Literature reveals increased suicidal ideation in the general population during pandemic. However, few COVID-19 studies comprehensively assessed factors associated with suicidal ideation, and mixed findings were observed. We aimed to examine prevalence and correlates of suicidal ideation in general public during the peak of fifth COVID-19 wave in Hong Kong based on a broad array of relevant measures.

Methods: This survey assessed 14,709 community-dwelling adults during March 15–April 3, 2022. Comprehensive assessment was administered including socio-demographics, pre-existing mental/physical morbidity, mental-health symptoms, resilience, loneliness, coping strategies, and pandemic-related factors. Presence of suicidal ideation was evaluated by ratings of item 9 on Patient-Health-Questionnaire-9.

Results: A total of 2,249 (15.3%) participants exhibited suicidal ideation. Multivariable-regression analysis found that being single and unemployed, pre-existing mental disorder, more severe depressive and anxiety symptoms, higher levels of loneliness and engagement in avoidant coping were significantly associated with suicidal ideation. Conversely, attaining tertiary educational level or above, greater resilience and adopting problem-focused coping were associated with lower likelihood of suicidal ideation. Although univariate-analyses revealed that a number of pandemic-related factors were linked to suicidal ideation, none remained significant in the multivariable model.

Conclusion: A significant proportion of people experienced suicidal ideation during the peak of fifth COVID-19 wave. Risk and protective factors identified would facilitate early identification of high-risk individuals and provision of targeted interventions to minimize suicidal ideation and risk of self-harm. Caution should be exercised due to study limitations of a cross-sectional design which precluded establishing causality among variables, and reliance on self-reported data.

KEYWORDS

suicidal ideation, COVID-19, survey, coping strategies, pre-existing mental disorders, loneliness

Introduction

Coronavirus disease (COVID-19) was declared a global pandemic by the World Health Organization in March 2020 (1), for imposing public health crisis. COVID-19 literature conducted in the community consistently demonstrated its profound impacts on both physical and mental health outcomes, including anxiety, depressive symptoms and psychological distress (2, 3). The effects of the pandemic itself combined with the prolonged implementation of social containment policies led to indirect socioeconomic repercussions, including economic downturn (4), social isolation (5), unemployment (6), and barriers to access mental health services (7) due to public health policies might in turn increase suicidality (8).

An elevated risk of suicide has been consistently linked to pandemic outbreaks across the world (9), with increased completed suicide rate in the United States during the 1918–1919 influenza pandemic (10), and increased rate of suicidal attempts during Ebola outbreak (11). Similarly, increased likelihood of suicide behaviors were observed during the COVID-19 pandemic (12–14). Hong Kong (HK) was the epicentre of the Severe Acute Respiratory Syndrome (SARS) in 2003, which caused 1,755 infections and 300 fatalities (15), and endured months of social unrest in 2019 just before the first local outbreak of COVID-19. Previous studies found an increased suicide rate in the elderlies during SARS epidemic in HK (15, 16). Throughout the whole 2021, there were fewer than 4,000 COVID-19 cases reported in HK (17). HK then experienced the fifth COVID-19 wave after the emergence of the Omicron variant in December 2021, with the 7-day rolling average of COVID-related deaths reaching 3.73 per 1,000 people at the peak, the highest worldwide (18, 19). However, until now, there has been lack of research evaluating suicidal ideations in the general population of HK that had this distinctive pandemic experience.

Suicidal ideation is defined as thinking about, considering or planning suicide (20). It is critical to understand suicidal ideation, which is a strong predictor of subsequent suicide attempts and completed suicides (21). Detecting its prevalence, risk factors and protective factors in the general population is essential for informing effective suicide prevention strategies. Development of suicidal ideation is multifactorial and involves a complex interplay between biological and psychosocial determinants (22). Some sociodemographic characteristics (such as younger age, socioeconomic disadvantage, single marital status and unemployment) and COVID-19 pandemic-related factors (such as contracting COVID-19 and social containment measures) are reported to be associated with suicidal ideations (23–27). Patients with pre-existing mental disorders are more likely than healthy persons to suffer an emotional response to the COVID-19 pandemic, leading to relapse or worsening of symptoms (7). For instance, people with a pre-existing mood or anxiety disorder had considerably higher scores of COVID-19-related traumatic stress symptoms than individuals without a current mental condition (28). Furthermore, while previous studies have consistently reported loneliness as a significant risk factor for suicidal ideation (24, 29–31), there is a gap in the literature simultaneously encompassing other protective psychosocial measures [e.g., different coping styles and resilience that have been linked to improved mental health outcomes in other contexts (32)] in studying suicidal ideations during COVID-19 pandemic. Relatively few studies have been conducted to systematically evaluate a broad range of factors associated with suicidal ideations in the general population during the COVID-19 pandemic.

To this end, the current study aimed to assess the prevalence of suicidal ideation among the general population amidst the peak of the fifth COVID-19 wave in HK (March–April, 2022). Importantly, we examined the correlates of suicidal ideation across a comprehensive array of variables encompassing socio-demographics, pre-existing illness profile, mental health symptoms, psychosocial measures as well as pandemic-related factors.

Materials and methods

Participants and study setting

This cross-sectional survey aimed to recruit community-dwelling adults aged 18 years or above in HK from March 15 to April 3, 2022 (33), during which the city was experiencing the peak of the fifth COVID-19 wave. It was estimated that approximately half of the population (3.6 million) have contracted the infection during the fifth wave by mid-March (34), and public health containment and social-distancing measures were further tightened in response to the surge of COVID cases (17). Details of the study design have been described in our recently published report (33), which examined the association between COVID-19 perseverative cognition and depression, and the moderating effect of potential risk and protective factors on this association in the general public. Briefly, we adopted snowballing sampling technique for data collection, with an online anonymous self-rated questionnaire being administered on a Qualtrics survey platform.[1] Virtual snowballing sampling is a commonly-used recruitment strategy during COVID-19 pandemic [e.g., (35–37)], which enables researchers to obtain a large sample within a short period of time and to minimize the interference of stringent control measures on data collection. The survey was disseminated through social media platforms (e.g., Facebook, Instagram, Twitter, WhatsApp), universities (via emails), and the Hong Kong Public Opinion Research Institute (HKPORI) which sent email invitations with survey link to the members of its probability- and non-probability- based online panels of adult HK residents. HKPORI is a well-established survey agency which has executed numerous

1 https://www.qualtrics.com

independent public surveys for academic institutions and government departments in HK (38). Respondents were encouraged to forward the survey link to their social networks for study participation. Survey participation was on a voluntary basis and online informed consent was obtained before questionnaire assessment. The survey took around 20 min to complete. The study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKW). The survey received 20,971 responses. Respondents who were not residing in HK during the study period, did not provide consent or failed to complete the questionnaire items on the primary measure of the current study (i.e., the Patient Health Questionnaire [PHQ-9] including the last item which assessed self-reported suicidal ideation) were excluded. A total of 14,709 respondents constituted the final sample for the current analysis.

Assessments

The self-rated study assessment comprised four sections including sociodemographic, illness profile and mental health symptoms, psychosocial measures, and COVID-19-related factors. Sociodemographic characteristics included age, gender, marital status, highest attained educational level, employment status, size of residential housing and monthly household income. Illness profile included pre-existing mental health diagnosis, alcohol/substance use, and chronic physical disease.

Concerning mental health symptoms, depressive and anxiety symptom severity were assessed by Patient Health Questionnaire-9 [PHQ-9; (39, 40)] and Generalized Anxiety Disorder-7 scale [GAD-7; (41, 42)], respectively, with both scales using a 4-point Likert scale ranging from 0 (never) to 3 (nearly every day). A validated Chinese version of Obsession with COVID-19 Scale [OCS; (43, 44)] was administered to measure the frequency of persistent and disturbing thinking about COVID-19, within a 2-week timeframe on a 5-point Likert scale ranging from 0 (not at all) to 4 (nearly every day). In the current study, depressive symptom severity was quantified by the sum of the items 1 to 8 on PHQ-9. Sleep quality and disturbance were assessed using Insomnia Severity Index [ISI; (45, 46)]. For all of the symptom scales, higher scores indicated greater symptom severity. Following the method of previous studies examining suicidal ideations in general public during COVID-19 (26, 47), an item 9 on the PHQ-9, namely "During the past 2 weeks, how often have you been troubled by the notion that you would be better off dead or hurting yourself?," was used to evaluate the presence of suicidal ideation. Specifically, participants who responded to an item 9 as "not at all" (i.e., rating = 0) were considered having no suicidal ideation, whereas those whose rating was 1–3 (i.e., "several days," "more than half the days," or "nearly every day") were categorized as having suicidal ideation.

Regarding psychosocial measures, participants' coping strategies were assessed by an adapted Coping Orientation to Problems Experienced Inventory–Brief [Brief-COPE; (48, 49)], which used a 4-point Likert scale ranging from 0 (never) to 3 (always). The 14 items of the adapted Brief-COPE were grouped into 3 copying styles based on previous factor-analytic study (50), namely avoidant, emotion-focused and problem-focused coping styles for subsequent analysis. A higher item sum score indicated a higher level of engagement in that particular coping style. The Chinese version of the three-item UCLA Loneliness Scale was applied to measure loneliness on a three-factor structure (51, 52). The Brief Resilience Scale [BRS; (53, 54)] was used to assess resilience levels on a 5-point Likert scale (1 [strongly disagree] to 5 [strongly agree]), with higher scores indicating greater resilience. Evaluation of COVID-19-related factors comprised items assessing history of contracting COVID-19 infection, receipt of vaccination, exposure to COVID-19-related information, COVID-19-related stressors experienced, specific infection control measures (e.g., under quarantine, mandatory COVID-19 testing) experienced and associated distress. Details of assessment of COVID-19 related factors are summarized in Supplementary Table S1.

Statistical analysis

First, a series of univariate binary logistic regression analyses were conducted to examine the association of suicidal ideation status (yes vs. no) with a broad array of variables covering socio-demographics, illness profiles and mental health symptoms, psychosocial measures and COVID-19 related factors. Then, those variables that were found to be statistically significant in the preceding univariate analyses were then included in the multivariable binary logistic regression model, based on backward Wald statistics, to determine factors which were independently associated with suicidal ideation. All analyses were conducted using SPSS 23.0, with significance level set as $p < 0.05$.

Results

Sample characteristics and prevalence of suicidal ideation

Table 1 summarizes the characteristics of the study sample. A total of 52.9% participants were women, and 14.3, 16.0, 17.4, 19.2 and 33.1% were aged 18–29, 30–39, 40–49, 50–59, and ≥60 years, respectively. Slightly more than half of the sample (56.4%) were married, and 35% attained tertiary educational level. Based on the ratings of item 9 on PHQ-9, 15.3% ($n = 2{,}249$) participants were classified as having suicidal ideation, including 10.7% ($n = 1{,}570$) seldom reported suicidal ideation, 2.8% ($n = 413$) often had suicidal ideation and 1.8% ($n = 266$) always reported suicidal ideation over the past 2 weeks of survey assessment.

Correlates of suicidal ideation

As shown in Table 2, participants' age, educational level, marital status, employment status, size of residential housing and monthly household income were significantly related to suicidal ideation in univariate regression analyses. Regarding illness profile and mental health symptoms, ratings on PHQ-9, GAD-7, OCS and ISI were associated with suicidal ideation. Table 3 shows that UCLA Loneliness Scale scores, BRS scores, and higher levels of engagement with avoidant and problem-focused coping styles were significantly related to suicidal ideation. For pandemic-related factors, history of COVID-19 infection, vaccination status, history of mandatory testing/quarantine, number of COVID-19 related stressors, exposure on reading pandemic-related information, and level of distress due to

TABLE 1 Descriptive characteristics of the study sample.

Variables of interest	Number (%)/mean (SD)
Socio-demographics	
Gender, female	7,653 (52)
Age, years	
18–29	2,100 (14.3)
30–39	2,346 (16.0)
40–49	2,563 (17.4)
50–59	2,823 (19.2)
60 or above	4,876 (33.1)
Education	
Secondary level or below	9,554 (65.0)
Tertiary level or above	5,153 (35.0)
Marital status	
Single	5,023 (34.2)
Married	8,296 (56.4)
Divorced/widowed	1,388 (9.4)
Employment status	
Working/student/housewife	10,344 (70.3)
Unemployed	1,090 (7.4)
Retired	3,272 (22.3)
Size of residential housing, square feet	
Less than 300	2,727 (18.8)
301–500	5,066 (34.9)
Above 501	6,743 (46.3)
Household income (HKD, monthly)[a]	
25,000 or below	6,711 (46.2)
Above 25,000	7,805 (53.8)
Illness profile and mental health symptoms	
Chronic physical diseases, yes	4,887 (33.7)
Alcohol/ substance abuse, yes	683 (4.7)
Pre-existing mental disorder, yes	1,205 (8.3)
Depressive symptoms (PHQ-9)	6.37 (5.6)
Anxiety symptoms (GAD-7)	5.58 (5.5)
Perseverative cognition on COVID-19 (OCS)	4.17 (3.6)
Insomnia symptoms (ISI)	8.38 (6.0)
Psychosocial measures	
Avoidant coping style	10.43 (2.8)
Emotion-focused coping style	10.22 (3.0)
Problem-focused coping style	6.37 (2.1)
Loneliness	4.46 (1.7)
Resilience	19.73 (4.6)
COVID-19 related factors	
Distress from experiencing the tightening of social-distancing measures	5.21 (3.5)
History of COVID-19 infection, yes	3,496 (23.8)
COVID-19 vaccination received	
0–2 doses	8,058 (56.8)
3 doses	6,124 (43.2)
Mandatory testing/ quarantine, yes	4,360 (31.4)
Number of COVID-19 related stressors	
0–2	11,235 (79.4)
3–5	2072 (14.6)
6–8	841 (6.0)
Time spent on reading COVID-19 related information	
<1 h per day	7,095 (49.9)
1–3 h per day	5,288 (37.2)
≥4 h per day	1843 (12.9)

COVID, coronavirus; GAD-7, Generalized Anxiety Disorder-7 scale; HKD, Hong Kong dollars; ISI, Insomnia Severity Index; OCS, Obsession with COVID-19 Scale; PHQ-9, Patient Health Questionnaire-9; SD, standard deviation.

[a] As of 9th March 2023, 1HKD = 0.13 USD.

social-distancing measures were associated with suicidal ideation in univariate regression analyses.

A multivariable logistic regression analysis revealed that attainment of tertiary educational level or above, greater resilience, and adoption of problem-focused coping style were independently associated with decreased likelihood of experiencing suicidal ideation (Table 4), while the relationship between older age (≥60 years) and suicidal ideation approached statistical significance ($p = 0.056$). Conversely, single marital status, being unemployed, pre-existing mental disorder, more severe depressive and anxiety symptoms, higher levels of loneliness, and engagement in avoidant coping style were associated with increased risk of suicidal ideation.

Discussion

The current study aimed to examine the prevalence and correlates of suicidal ideation in the general population (predominantly Chinese) during the peak of the fifth COVID-19 wave in HK. This is among the few studies that comprehensively assessed a wide array of factors associated with suicidal ideation in the general public amidst the pandemic, encompassing socio-demographics, illness profile and mental health symptoms, psychosocial variables of loneliness, resilience and coping strategies, as well as COVID-19 related variables. Our results showed that approximately one-sixths (15.3%) of the study sample experienced suicidal ideation amidst the fifth wave of pandemic. This is slightly higher than the pooled prevalence estimate of suicidal ideation during COVID-19 reported in a recent meta-analysis (26), as well as those observed in the Chinese population from mainland China (13.4%) and Taiwan (10.8%) (26, 54). The distinctive experiences of HK population with unique prior exposure of the SARS epidemic and social unrest just before COVID-19 may have also contributed to the susceptibility to increased suicidal ideation during the fifth wave of pandemic.

Our findings are generally consistent with the notion of the complex interplay among various risk and protective factors for suicidal ideation (22). We affirmed results of previous COVID-19

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TABLE 2 Univariate regression analyses on the relationship of suicidal ideation with socio-demographics, illness profile and mental health symptoms.

Variables of interest[a]	No suicidal ideation	Suicidal ideation	Odds ratio (95% CI)	Value of *p*
Socio-demographics				
Age, years				
18–29	1,557 (12.5)	544 (24.2)	1.00 (reference)	–
30–39	1865 (15.0)	482 (21.4)	0.74 (0.64–0.85)	<0.001
40–49	2,144 (17.2)	419 (18.6)	0.56 (0.49–0.65)	<0.001
50–59	2,418 (19.4)	405 (18.0)	0.48 (0.42–0.55)	<0.001
≥60	4,476 (35.9)	400 (17.8)	0.26 (0.22–0.30)	<0.001
Gender (male)	5,818 (47.4)	993 (45.5)	1.00 (reference)	–
Gender (female)	6,464 (52.6)	1,189 (54.5)	1.08 (0.98–1.18)	0.112
Education				
Secondary level or below	7,901 (63.4)	1,653 (73.5)	1.00 (reference)	–
Tertiary level or above	4,557 (36.6)	595 (26.5)	0.62 (0.57–0.69)	<0.001
Marital status				
Married/stable relationship	7,362 (59.1)	934 (41.5)	1.00 (reference)	–
Single	3,965 (31.8)	1,059 (47.1)	2.11 (1.91–2.31)	<0.001
Divorced/ widowed	1,132 (9.1)	256 (11.4)	1.78 (1.53–2.07)	<0.001
Employment status				
Working/ students/housewife	8,676 (69.6)	1,668 (74.1)	1.00 (reference)	<0.001
Unemployed	790 (6.4)	301 (13.4)	1.98 (1.71–2.28)	<0.001
Retired	2,992 (24.0)	280 (12.5)	0.49 (0.43–0.56)	<0.001
Size of residential housing, square feet				
Less than 300	2,104 (17.1)	624 (28.0)	1.00 (reference)	–
301–500	4,289 (34.8)	777 (34.9)	0.61 (0.54–0.69)	<0.001
Above 501	5,918 (48.1)	825 (37.1)	0.47 (0.42–0.53)	<0.001
Household income (HKD, monthly)[b]				
25,000 or below	5,516 (44.8)	1,195 (53.7)	1.00 (reference)	–
Above 25,000	6,775 (55.2)	1,030 (46.3)	0.70 (0.64–0.77)	<0.001
Illness profile and mental health symptoms				
Chronic physical diseases, no	8,294 (67.4)	1,336 (60.2)	1.00 (reference)	
Chronic physical diseases, yes	4,003 (32.6)	884 (39.8)	1.37 (1.25–1.50)	<0.001
Alcohol/ substance abuse, no	11,827 (96.2)	2007 (90.4)	1.00 (reference)	
Alcohol/ substance abuse, yes	471 (3.8)	213 (9.6)	2.66 (2.25–3.15)	<0.001
Pre-existing mental disorder, no	11,556 (94.0)	1756 (79.1)	1.00 (reference)	
Pre-existing mental disorder, yes	741 (6.0)	464 (20.9)	4.12 (3.63–4.67)	<0.001
Depressive symptoms (PHQ-9)[c]	5.2 (4.6)	13.3 (5.7)	1.29 (1.28–1.30)	<0.001
Anxiety symptoms (GAD-7)	4.5 (4.6)	12.1 (5.7)	1.27 (1.25–1.28)	<0.001
Perseverative cognition on COVID-19 (OCS)	3.8 (3.4)	6.0 (4.1)	1.17 (1.16–1.19)	<0.001
Insomnia symptoms (ISI)	7.4 (5.4)	13.7 (6.3)	1.18 (1.17–1.19)	<0.001

CI, confidence interval; COVID, coronavirus; GAD, generalized anxiety disorder scale; HKD, Hong Kong dollars ISI Insomnia Severity Index; OCS, obsession with COVID-19 scale; PHQ, patient health questionnaire; SD, standard deviation.

[a] Variables of interest are presented in number and percentage (%) except scores on PHQ-9, GAD-7, OCS and ISI, which are presented in mean and standard deviation.

[b] As of 9th March 2023, 1HKD = 0.13 USD.

[c] Depressive symptom severity was quantified as the sum of ratings from item 1 to 8 on PHQ-9, excluding item 9, which measured suicidal ideation.

studies that a number of key socio-demographic characteristics were significantly associated with increased risk of suicidal ideation (6, 23–26). Being single, unemployed and less educated are well-established risk factors for suicidal ideation and behaviors in the literature, irrespective of the pandemic. Alternatively, our observation that aged ≥60 years was related to the lowest likelihood of having

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TABLE 3 Univariate regression analyses on the relationship of suicidal ideation with psychosocial measures and COVID-19 related factors.

Variables of interest[a]	No suicidal ideation (*n* = 12,460)	Suicidal ideation (*n* = 2,249)	Odds ratio (95% CI)	Value of *p*
Psychosocial measures				
Avoidant coping style	10.0 (2.5)	12.7 (3.1)	1.42 (1.39–1.45)	<0.001
Emotion-focused coping style	10.2 (3.0)	10.2 (2.7)	1.00 (0.98–1.01)	0.492
Problem-focused coping style	6.8 (2.1)	6.6 (1.9)	1.06 (1.04–1.08)	<0.001
Loneliness	4.2 (1.5)	6.0 (2.0)	1.72 (1.68–1.77)	<0.001
Resilience	20.5 (4.2)	15.7 (4.2)	0.77 (0.76–0.78)	<0.001
COVID-19 related factors				
Distress due to social-distancing measures	4.98 (3.4)	6.49 (3.3)	1.14 (1.13–1.16)	<0.001
Never have COVID-19 infection	9,557 (76.7)	1,656 (74.0)	1.00 (reference)	–
History of COVID-19 infection, yes	2,903 (23.3)	582 (26.0)	1.18 (1.06–1.30)	0.002
COVID-19 vaccination doses received				
0–2 doses	6,688 (55.5)	1,382 (64.0)		
3 doses	5,357 (44.5)	778 (36.0)	0.70 (0.64–0.77)	<0.001
Mandatory testing/ quarantine· no	8,151 (69.3)	1,356 (64.5)	1.00 (reference)	–
Mandatory testing/ quarantine, yes	3,615 (30.7)	745 (35.5)	1.24 (1.12–1.37)	<0.001
Number of COVID-19 related stressors				
0–2	10,191 (84.9)	831 (38.5)	1.00 (reference)	–
3–5	1,408 (11.7)	857 (39.8)	4.52 (4.04–5.05)	<0.001
6–8	408 (3.4)	468 (21.7)	10.2 (8.8–11.8)	<0.001
Time spent on reading COVID-19 related information				
<1 h per day	6,264 (51.9)	842 (38.7)	1.00 (reference)	–
1–3 h per day	4,431 (36.7)	861 (39.5)	1.45 (1.30–1.60)	<0.001
≥4 h per day	1,375 (11.4)	475 (21.8)	2.57 (2.27–2.92)	<0.001

CI, confidence interval; COVID, coronavirus.

[a] All of the variables of psychosocial measures and distress due to social-distancing measures are presented in mean and standard deviation, while the remaining variables of COVID-19 related factors are presented in number and percentage (%).

suicidal ideation (albeit of trend-wise significance) suggested that people of older age might be relatively susceptible to the development of suicidal ideation during pandemic. This in fact corroborated with some studies examining suicidal ideation during the COVID-19 using online survey design (23, 25, 26). Of note, we are cautious that web-based survey data may potentially bias the results in favor of those more resourceful older-aged participants (among the elderly population) who had access to online platforms and were equipped with the skills to administer the survey questionnaire (55). This is intriguing given the contrary finding that elderly people, but not the younger-age group, had an increased suicide rate during SARS epidemic in HK (15, 16). Alternatively, it is possible that compared to SARS, COVID-19 pandemic is far more long-lasting with more prolonged public health and social-distancing measures for infection control. Yet, older-aged people are in general less likely to be employed or engaged in activities that require frequent face-to-face interactions. Hence, they may be comparatively less affected by the stringent public health polices, with lower degree of persistent exposure to COVID-19 related stressors such as unemployment and financial uncertainty, and the consequent adverse psychological impact including suicidal ideation.

We found that more severe depressive and anxiety symptoms, and the presence of pre-existing mental disorder were independently associated with raised likelihood of developing suicidal ideation. Substantial evidence has noted that individuals with mental disorders are more vulnerable to increased psychological distress than those without mental disorders during the pandemic (7, 28). It is also well-acknowledged that mental disorders represent a key predictor of suicidal ideation and behaviors (56, 57). Consistent with prior research (25), our findings demonstrated that pre-existing mental disorder was the strongest factor associated with suicidal ideation in the general population during the fifth COVID-19 wave. In line with a large body of research (and disregard of the pandemic) (27, 47, 55, 58, 59), we observed that greater depressive and anxiety symptom severity were significantly related to suicidal ideation. Accumulating data have further suggested that these mood symptoms may even persist after the pandemic (60). Overall, our results highlight the significance of early identification of and prompt treatment to depressive and anxiety symptoms, as well as the need to optimize psychiatric treatment for pre-existing mental disorders so as to minimize the risk of suicidal ideation and subsequent self-harm attempts during the pandemic. In this regard, health and welfare polices ensuring adequate access and availability of mental health services and mobilizing community service support would facilitate early detection of high-risk subgroup and timely provision of effective

TABLE 4 Multivariable logistic regression analysis for factors associated with suicidal ideation.

Variables	Odds ratio (95% CI)	*Value of p*
Socio-demographics		
Age, years		
18–29	1.00 (reference)	–
30–39	0.98 (0.81–1.20)	0.86
40–49	0.90 (0.73–1.11)	0.32
50–59	1.06 (0.85–1.33)	0.61
≥ 60	0.79 (0.61–1.01)	0.056
Education		
Secondary level or below	1.00 (reference)	–
Tertiary level or above	0.80 (0.70–0.91)	<0.001
Marital status		
Married/ stable relationship	1.00 (reference)	–
Single	1.33 (1.14–1.54)	<0.001
Divorced/widowed	1.20 (0.98–1.47)	0.085
Employment Status		
Working/students/housewife	1.00 (reference)	–
Unemployed	1.31 (1.08–1.60)	0.006
Retired	1.20 (0.95–1.52)	0.126
Size of residential housing, square feet		
Less than 300	1.00 (reference)	
301–500	0.89 (0.75–1.04)	0.148
Above 501	0.92 (0.78–1.10)	0.356
Household income (HKD, monthly)		
25,000 or below	1.00 (reference)	
Above 25,000	0.96 (0.84–1.10)	0.589
Illness profile and mental health symptoms		
Chronic physical diseases, no	1.00 (reference)	–
Chronic physical diseases, yes	0.90 (0.77–1.05)	0.187
Alcohol/ substance abuse, no	1.00 (reference)	–
Alcohol/ substance abuse, yes	1.09 (0.86–1.40)	0.470
Pre-existing mental disorder, no	1.00 (reference)	–
Pre-existing mental disorder, yes	1.51 (1.23–1.86)	<0.001
Depressive symptoms	1.14 (1.12–1.16)	<0.001
Anxiety symptoms	1.08 (1.06–1.10)	<0.001
Perseverative cognition on COVID-19	0.99 (0.97–1.01)	0.340
Insomnia symptoms	1.00 (0.99–1.02)	0.344
Psychosocial measures		
Avoidant coping style	1.13 (1.10–1.16)	<0.001
Problem-focused coping style	0.88 (0.85–0.91)	<0.001
Loneliness	1.15 (1.11–1.19)	<0.001
Resilience	0.92 (0.91–0.94)	<0.001
COVID-19 related factors		
Distress due to social-distancing measures	1.01 (0.99–1.03)	0.328
Never have COVID-19 infection	1.00 (reference)	–
History of COVID-19 infection, yes	1.04 (0.90–1.19)	0.608

(Continued)

TABLE 4 (Continued)

Variables	Odds ratio (95% CI)	*Value of p*
COVID-19 vaccination doses received		
0–2 doses	1.00 (reference)	–
3 doses	0.90 (0.79–1.02)	0.091
Mandatory testing/ quarantine· no	1.00 (reference)	–
Mandatory testing/ quarantine, yes	1.08 (0.96–1.23)	0.196
Number of COVID-19 related stressors		
0–2	1.00 (reference)	–
3–5	1.08 (0.92–1.25)	0.357
6–8	1.18 (0.95–1.47)	0.144
Time spent on reading COVID-19 related information		
<1 h per day	1.00 (reference)	–
1–3 h per day	1.00 (0.88–1.15)	0.957
≥4 h per day	1.01 (0.84–1.22)	0.920

CI, confidence interval; COVID, coronavirus; HKD, Hong Kong dollars.

intervention to alleviate mood symptoms and reduce self-harm risk (61). Emerging evidence has also demonstrated the effectiveness of tele-health care including mental health screening, assessment and treatment of depression (62), and indicated this approach as a feasible and reliable alternative of standard healthcare delivery during pandemic (63, 64). Future research should concentrate on evaluating tailor-made mental health interventions to meet the specific need of this high-risk subgroup, who have pre-existing mental disorders and/or persistent mood symptoms, during and after the pandemic (7).

Our results demonstrated that greater resilience and higher level of engagement in problem-focused coping style were significantly associated with lower risk of developing suicidal ideation during the peak of fifth pandemic wave. Alternatively, higher degree of loneliness and adoption of avoidant coping style were linked to suicidal ideation. This generally concurs with the research conducted before COVID-19 showing that avoidant coping strategies are a risk factor for suicidal ideation (65), whereas problem-focused coping can be protective from self-harm (66, 67). Resilience is the capacity and dynamic process of adaptively overcoming stress and adversity while maintaining normal functioning (68). Higher level of resilience has been found to reduce depressive symptoms (69), mitigate the effect of pandemic-related stress on negative mental health outcomes (70), and to be a protective factor against suicide risk (71, 72). Our finding that loneliness was independently associated with suicidal ideation is in line with previous studies, including those conducted during the COVID-19 pandemic, showing that loneliness is a significant predictor of suicidal ideation and behavior (24, 30, 73). It is noteworthy that loneliness and social connection are separate constructs with overlapping features (74). Loneliness, defined as the subjective perception of insufficient social contact, can exacerbate feelings of vulnerability and heighten hypervigilance to social threats, which adversely affect psychosocial functioning and may result in poorer mental health outcomes (75). In this regard, loneliness may be more closely associated with suicidal ideation and behavior than other aspects of social connection, such as social distancing, emotional support and interpersonal conflict (76). An earlier local COVID-19 study also found that subjective feelings of loneliness were associated with increased mental health symptoms among the general public in HK (77). Taken together, these results underscore the importance of promoting resilience (at individual and community levels, for instance via practicing self-care and cultivating community) (72, 78), social support (i.e., reduction of sense of loneliness) and the use of adaptive coping as effective strategies to minimize the adverse impact of pandemic on increased suicidal ideation and self-harm risk (79). On the other hand, although our univariate analyses revealed that a number of COVID-19 related factors, such as number of pandemic-related stressors, distress due to social-distancing measures, history of contracting COVID-19 and vaccination status, are related to suicidal ideation, none of these variables remained significant in the final multivariable model. This is contrary to some past studies which suggested that certain COVID-19 related factors including experience of quarantine and confirmed infection were significantly related to higher odds of suicidal ideation (23, 26, 27). It might be possible that an effect of COVID-19 related factors on suicidal ideation may be fully mediated by other variables included in our final regression model, which incorporated a comprehensive range of candidate factors encompassing illness profile, mental health symptoms and psychosocial measures. Alternatively, it is important to take into consideration the broader context beyond the impact of the fifth pandemic wave. Previous COVID-19 pandemic waves, the accompanying financial/economic crisis (4), and ensuing geopolitical shifts (80) could also pose influences on individuals' mental wellbeing and suicidality. These broader-contextual factors can compound the stress and isolation imposed by pandemic circumstances, intensifying feelings of loneliness and vulnerability to psychological distress (81). As such, future investigation should clarify the complex interplay between these factors on mental health outcomes.

The study has several limitations. First, the cross-sectional study design precludes establishment of causal relationship. Longitudinal research is warranted to determine the course of suicidal ideations over time and its predictors. Second, although an item 9 on PHQ-9 is a commonly used measure in psychiatric research to determine the presence of suicidal ideation (21, 26, 47, 82), scales that are

specifically developed for suicidal ideation/suicide risk assessment would provide a more comprehensive and accurate evaluation (83). Third, the snowballing sampling strategy is non-probabilistic in nature and may compromise the representativeness of the sample and study results. Additionally, the questionnaire was distributed and administered online, people with limited access to smartphone or computers would be excluded from the survey, resulting in some selection bias. Nevertheless, online health survey with virtual snowballing strategy is a widely-used and reliable method to assess psychological distress in the general population amidst the COVID-19 pandemic, particularly in the face of difficulties to access and recruit participants under the circumstances of stringent community containment measures to curb the spread of infection (84). Fourth, psychological symptom assessment was based on participants' self-reporting (though these scales are well-validated and commonly used in research), which may not well align with the corresponding rating instruments administered by mental health professionals.

Our study showed that around 15% of the general population in HK displayed suicidal ideation during the peak of the fifth wave of the COVID-19 pandemic. People who are single, less educated and unemployed, have pre-existing mental disorder, higher levels of loneliness, depressive and anxiety symptoms, and engagement of avoidant coping style are significantly more likely to experience suicidal ideation. Conversely, greater resilience and the use of problem-focused coping strategies are protective factors for developing suicidal ideation. Prospective follow-up investigation is required to track the trajectories of suicidal ideation and behaviors as well as their predictors in relation to the subsequent course of COVID-19 pandemic and the post-pandemic era.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKW). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

WiC and CW designed and conceptualized the study. GW, JL, YS, JC, VF, and RC prepared the questionnaire assessment. HL and JC conducted the statistical analysis. HL wrote the first draft of the manuscript. HL, WiC, and JC interpreted the study data. WiC and HL revised and finalized the manuscript. All authors provided critical feedback to the manuscript and have approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2023.1252600/full#supplementary-material.

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Hospital pharmacists' mental health during home isolation in the post-pandemic era of COVID-19: influencing factors, coping strategies, and the mediating effect of resilience

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Objective: There is a notable research gap on the mental health challenges faced by hospital pharmacists in the post-pandemic era. Therefore, the present study aims to explore mental health status, influencing factors, coping strategies, and the mediating effect of resilience of home quarantine hospital pharmacists (HQHPs).

Methods: An embedded mixed-method study was conducted in Zhengzhou, a megalopolis in central China, from 20 October to 3 November 2022. For the qualitative study, semi-structured interviews and focus group discussions were conducted among HQHPs to understand their mental health state，the factors that affect their mental health, and the alleviating strategies they used. For the quantitative study, the Generalized Anxiety Disorder Scale (GAD-7) and the Chinese version of the Connor-Davidson Resilience Scale (CD-RISC-25) were used to explore the mental health level of HQHPs. Meanwhile, the mediating effect of resilience was explored and verified with the bootstrap method or the structural equation model.

Results: 20 HQHPs participated in the qualitative study. Two themes were identified in terms of the factors that influenced the HQHPs' mental health levels. The positive factors include optimism, family company, and connection with friends, while the negative factors include inadequate supplies, inadequate information, and other emergencies. 210 HQHPs participated in the quantitative study, with a median resilience score of 66 [55.75, 74] in the lowest score range and an anxiety score of 5 [2, 7] in the mild anxiety range. The correlation analysis showed that nine of the 10 influencing factors identified in qualitative research were positively correlated with CD-RISC-25 scores and negatively correlated with the GAD-7 score. The mediating effect of resilience on anxiety was significant (95% bootstrap CI [−1.818, −0.384], $p<0.001$; or 95% bootstrap CI [−1.174, −0.430], $p<0.001$).

Conclusion: Even in the post-epidemic era, hospital pharmacists face psychological challenges. They actively address these issues based on accumulated experience and a stabilized mindset. In this process, resilience plays a significant mediating role.

KEYWORDS

home quarantine hospital pharmacists (HQHPs), COVID-19, embedded mixed methods, resilience, mediating effect, mental health

Introduction

Coronavirus Disease 2019 (COVID-19) has left an indelible mark on community life, healthcare, and education (1, 2). Governments worldwide have responded with myriad measures, ranging from city lockdowns to social isolation, quarantines for infected populations, and home isolation (3). In particular, individuals working in healthcare settings, particularly hospital pharmacists and other healthcare workers (HCWs), are disproportionately susceptible to mental health challenges during this unprecedented crisis. China, being the first nation to face the challenges posed by COVID-19, implemented stringent quarantine measures to curb the spread of the virus within its borders and in other regions (4). After years of battling the COVID-19 virus and its variants, China's domestic epidemic prevention and control program transitioned to a normalized stage in 2022. Despite this progress, local and sporadic virus outbreaks have recently emerged in specific regions and cities (5). An illustrative case is the recent COVID-19 outbreak in Zhengzhou, the capital of central China's Henan Province, disrupted work for all practitioners. These individuals were compelled to stay home due to temporary lockdowns and controlled zones designed to stem the virus's spread. This situation stands out as uncommon on a global scale, where many regions have eased their epidemic containment measures. However, despite the worldwide impact of such extreme conditions, research on the specific consequences for the mental health of pharmacists remains relatively limited.

Quarantine has been shown to significantly reduce mental health levels (6–8). Brooks et al. (9) reviewed the psychological impact of quarantine and isolation and found negative psychological effects, including post-traumatic stress symptoms, confusion, insomnia, avoidance behaviors and confusion, highlighting the importance of reducing quarantine to a minimally required period of time. In the battle against COVID-19, pharmacists have become a crucial component of the healthcare system. Their contributions include formulating professional service guidelines for pharmacists and pharmacies, creating emergency drug lists, addressing and monitoring drug shortages, offering telemedicine services, conducting public education on infection prevention and disease management, as well as actively participating in clinical trials and drug evaluations (10, 11). However, compared to nursing staff and physicians, the psychological challenges associated with COVID-19 for hospital pharmacists have received relatively less attention (12). Studies performed prior to the COVID-19 outbreak have shown that pharmacists have a lower health-related quality of life and higher levels of anxiety than the general population and other health professionals, including physicians, nurses, and others (13, 14).

Anxiety is a prominent marker in researching the psychological well-being of HCWs during the COVID-19 pandemic for several key reasons. First, studies report that more than 25% of HCWs, particularly medical personnel, experience anxiety at significant levels (15). Second, anxiety reflects an emotional response that includes concerns, tension, and fear regarding potential threats, which makes it crucial to capture the emotional state of HCWs navigating stress and uncertainty (16). Third, the levels of anxiety in HCWs can affect their focus on patient safety and job performance, contributing to a better understanding of their professional responsibilities during epidemic responses (17). Last, anxiety is commonly associated with stressful events. Given the global impact of the COVID-19 pandemic, it serves as a critical marker for characterizing mental health levels in studying the psychological issues of healthcare professionals post-quarantine in the epidemic's aftermath.

Dealing with special situations arising from the epidemic, such as quarantine, is an essential concern in the post-epidemic era. Previous studies have reported a variety of coping strategies, such as establishing harmonious interpersonal relationships, building a good community environment, and creating a good climate of public opinion (18). These external pillars have played an instrumental role in surmounting adversities amidst the pandemic (19). In addition, personal factors such as a positive mindset, optimism, and inner drive are also important, with resilience being one of the individual inner drives that have been particularly highlighted in previous reports (16). Resilience, a critical concept in positive psychology, is the personal ability to cope with or overcome various perceived adversities and stress. Individuals with higher levels of resilience work through challenges using personal resources, strengths, and other positive psychological capital capacities, such as hope, optimism, and self-efficacy, to "bounce back" as a stronger person than before (20). Previous research has shown that physicians' and nurses' stress mindset and resilience could mitigate the negative outcomes of COVID-19 health anxiety by helping them view this stressful situation more positively and consider it a challenge rather than a threat (21). Hence, we seek to employ psychological resilience as a mediating variable to explain the possible intrinsic regulatory determinants that affect the response of HQHPs to anxiety.

Despite extensive research on healthcare workers' coping strategies, a significant research gap exists in understanding how HQHPs cope, particularly in the post-epidemic era. Examining the entire COVID-19 timeline, healthcare workers face distinct challenges requiring nuanced coping strategies from the pandemic through the transition period to the post-epidemic era. During the pandemic, prioritizing teamwork, providing practical support tools, and ensuring comprehensive pharmacist training are crucial to managing daily high-intensity pressure and fatigue (22–24). In the transition period, in addition to adaptation training and mental health support, open communication and self-management are vital to adapting to a new workplace and promoting mental well-being (25). In the post-epidemic era, healthcare workers may experience fatigue and emotional stress, requiring mental health support services, such as professional consultations and participation in support groups, along with promoting adequate rest and recovery time (26). For HQHPs in mainland China during the post-epidemic era, despite the lenient global epidemic prevention policies, they are obligated to undergo home isolation, leading to increased mental stress, physical stress, and

increased work burden (26). Consequently, the mental health challenges faced by hospital pharmacists in mainland China during home isolation require urgent attention and investigation (27).

Study aims

Given the unique circumstances outlined above, there is a critical need to understand the mental health status of HQHPs, identify influencing factors, explore coping strategies, and uncover potential intrinsic regulatory factors. In response to these considerations, this study focuses on anxiety as the outcome variable linked to mental health levels, with resilience serving as a mediator. The research aims to accomplish the following objectives: (1) clarify the current psychological well-being of HQHPs during home quarantine in the post-epidemic era; (2) analyze potential factors affecting the mental health levels of HQHPs, emphasizing the mediating role of psychological resilience; and (3) investigate potential strategies employed by HQHPs in addressing mental health issues.

Methods

Study design

Previous research in this field mainly relied on cross-sectional quantitative studies or qualitative investigations through in-depth interviews. While each method has strengths and limitations, our study employs a mixed-method embedded research design to explore mental health among HQHPs (28). This design seamlessly integrates both qualitative and quantitative methodologies, allowing for a comprehensive examination of the research question. By synthesizing data from these two approaches, we aim to capture information on multiple levels and dimensions, enriching our understanding of the research phenomenon. An advantageous aspect of this approach is the mutual validation between qualitative and quantitative components (29).

To achieve our research objectives, we followed the procedural steps outlined in mixed-method embedded research (30). First, we used qualitative research to gain an in-depth understanding of the psychological experience of quarantined hospital pharmacists and the multidimensional factors influencing their mental health in this exceptional situation, as well as to summarize their coping strategies. Second, a quantitative study was performed to validate the factors identified during the qualitative study and analyzed the mediating role of resilience. Finally, the results of the qualitative and quantitative studies were integrated. The detailed flow chart of the study is presented in Figure 1.

Settings and participants

HQHPs (20 October to 30 November 2022) were selected from several large hospitals in Henan province. These sample hospitals included the First Affiliated Hospital of Zhengzhou University, the Second Affiliated Hospital of Zhengzhou University, the Third Affiliated Hospital of Zhengzhou University, the 7th People's Hospital of Zhengzhou, Henan Children's Hospital, Henan Provincial Cancer Hospital, and Henan Coking Coal Central Hospital. With a combined capacity of 20,700 beds and approximately 730 pharmacists, these traditional large tertiary hospitals ranked among the best in central China (31). The inclusion criteria for the participants were (1) volunteered to participate in this study, (2) worked a minimum of 1 year in the department of pharmacy in the sample hospitals, and (3) had experienced quarantine between 20 October and 3 November 2022.

This study used a census approach, sampling all eligible HQHPs from the sample hospitals. The researcher communicated with the pharmacy department leaders in the sample hospitals to discuss the research objectives and plans. Subsequently, all eligible HQHPs were recruited by the pharmacy department leaders in their respective institutions. Finally, 240 pharmacists participated in this study, including clinical pharmacists, dispensing pharmacists, managers, information pharmacists, etc. A total of 240 questionnaires were sent, and 210 valid questionnaires were recovered (87.50%). Of the 210 participants in the quantitative study, 20 volunteered to participate in a qualitative interview study. Eight pharmacists participated in the one-on-one interview and 12 participated in focus group discussions (four in each group). Participant flow is shown in Supplementary Figure S1, and the demographic characteristics of all the participants are shown in Table 1.

Instruments

Resilience

The Chinese version of the Connor-Davidson Resilience Scale (CD-RISC-25) (20, 32), was used to evaluate individual resilience.

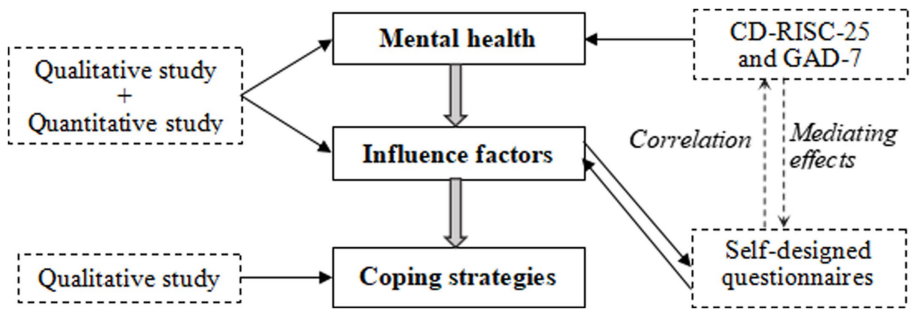

FIGURE 1
Research methodology.

TABLE 1 Demographic characteristics of all participants.

Item	Classification	Qualitative study	Quantitative study
		Number (%;n = 20)	*Number (%;n = 210)*
Gender	Male	5 (25.00)	52 (24.76)
	Female	15 (75.00)	158 (75.24)
Age	≤35	10 (50.00)	122 (58.10)
	36–50	6 (30.00)	71 (33.80)
	>50	4 (20.00)	17 (8.10)
Educational level	Technical secondary school	0 (0.00)	17(8.10)
	Junior college	1 (5.00)	19(9.05)
	Undergraduate	9 (45.00)	106 (50.47)
	Postgraduate	10 (50.00)	68 (32.38)
Working years	<10	9 (45.00)	107 (50.95)
	≥10	11 (55.00)	103 (49.05)
Marriage status	Unmarried	1 (5.00)	40 (19.05)
	Married	18 (5.00)	165 (78.57)
	Divorced	1 (5.00)	5 (2.38)
Professional title	Junior professional	0	54 (25.71)
	Intermediate professional	13 (65.00)	127 (60.48)
	Associate senior professional	6 (30.00)	23 (10.95)
	Senior professional	1 (5.00)	6 (2.86)
Days of continuous quarantine	0–7 days	5 (25.00)	81 (38.57)
	8–15 days	15 (75.00)	129 (61.43)

This valid and reliable scale (Cronbach's alpha = 0.963) comprises 25 items rated on a five-point Likert scale from 0 (not true at all) to 4 (true all the time). The total score ranges from 0 to 100, with a higher score indicating greater resilience. The scores for the lowest quartile range from 0 to 73, the second lowest quartile scores range from 74 to 82, the third quartile scores range from 83 to 90, and the fourth quartile scores range from 91 to 100 (33).

Anxiety

Anxiety levels were assessed using the 7-item Generalized Anxiety Disorder Scale (GAD-7), a well-validated tool with high reliability (Cronbach's alpha = 0.929). This instrument aggregates responses from seven questions designed to screen and diagnose generalized anxiety disorder (34). The respondents provide 4-point responses, ranging from 0 (not at all) to 3 (nearly every day), both in clinical practice and research. The cumulative scores, ranging from 0 to 21, are categorized as follows: normal (0–4), mild (5–9), moderate (10–14), and severe (15–21) anxiety. Participants with a total GAD-7 score ≥ 10 are identified as positive for anxiety screening (35).

Self-designed questionnaire

In the absence of available standardized questionnaires, a self-designed questionnaire was developed comprising 10 questions, guided by the influencing factors identified in the preliminary findings of the qualitative study (Supplementary Table S1). The self-designed questionnaire demonstrated satisfactory internal consistency, with Cronbach's alpha at 0.839. To ensure the clarity and completeness of the questions, a pilot study was conducted involving 20 HQHPs. The questionnaire was evaluated based on feedback received. After incorporating the suggestions provided by the participating HQHPs and making the necessary adjustments, the primary research was initiated.

Data collection and analysis

Qualitative study

For the qualitative survey, purposeful sampling was used to obtain participants from the HQHPs involved in the quantitative research. Due to the restrictions of the COVID-19 pandemic, all interviews were conducted by phone calls or video chat. After informed consent, semi-structured interviews or focus group discussions were led by one researcher (ZY) and recorded by another (XJL or XYW). An interview topic guide (Supplementary Table S2, designed by ZY and XJL before the interview) was piloted in an interview. Data saturation was reached after interviewing 8 HQHPs and three focus group discussions. All interviews took place from 20 October to 3 November 2022. Data saturation was defined as "no new themes or codes emerge from interviews."

The interview data were analyzed using a thematic analysis approach, a method to identify, analyze, and report patterns within the data widely used in qualitative research. The key steps include familiarization with the data, generating initial codes, searching and reviewing the themes, naming the themes, and producing the final report (36). Within 24 h after the interview, the interview data were transcribed verbatim by one researcher (ZY) and checked by two other researchers (XJL and XYW). After confirming that the transcriptions were correct, two researchers (ZY and XJL) independently completed the extraction of the codes and wrote the first draft of the themes and subthemes. Subsequently, the research group discussed the first draft and proposed comments and suggestions for theme structure and language expression. Under the guidance of a senior research expert, the research team compared and analyzed discrepancies and established the final themes and subthemes. The final draft were developed with the agreement of the research group, and appropriate representative quotes were selected to present the themes or subthemes. NVivo12 software was used to manage and analyze the data in the process described above. This study followed the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist (Supplementary Table S3) (37).

Quantitative study

For the quantitative study, the responses to the online survey were exported from Questionnaire Star to an Excel file (Excel version 2016; Microsoft Corp., Redmond, WA, United States). Data were cleaned, coded, and analyzed using IBM SPSS® (Armonk, NY, United States) statistical software version 26. Measurement data are expressed as median with [25% lower quartile; 75% upper quartile], and count data are expressed as percentages. Each participant's total score for CD-RISC-25 and GAD-7 was calculated by summing the individual

TABLE 2 The psychological state of HQHPs under quarantine.

Themes	Quotations
Negative emotions	Although we have experienced several outbreaks, this time I felt very sudden, just like when we were not allowed to leave the building at the beginning, we were still quite anxious *(G1P3)*.
	After the third day, I felt that I lacked a spiritual support at home *(P1)*.
Adaptation	After so many years, as a young person, I am not so scared of this virus now, I just think that it might be a bad cold, and I will just fight it off *(G3P3)*.
	When the epidemic first broke out, I felt very panicky and worried that I would be infected, but now that there is a vaccine and medication, I feel adapted and much better *(P6)*.
Experience accumulation	In terms of ourselves, this is controllable, because after all, we have experienced it *(G1P1)*.
	It's okay, after all, I've been through it so many times now, and I think I've had some experience with it, so it does not seem that bad *(G3P1)*.
Active coping	I just use that free time and I would feel so happy to be able to quiet my mind and write *(G2P4)*.
	The heart is empty, in fact, it has a little impact on the physical and psychological aspects, but on second thought, we still live a regular life, and it is more important to improve our immunity to deal with the epidemic *(P1)*.
	We all have to face it with a positive mindset because when you only face him with a positive mindset, your autoimmunity will be strong and the virus will not be able to attack your body easily, right? *(G2P1)*.

G, group; P, participant; For example, G1P1 means the first participant from the first group.

item scores. The Shapiro–Wilk test was used to assess data normality. Independent sample t-test or one-way ANOVA was used to examine differences in CD-RISC-25 and GAD-7 among demographic variables following a normal distribution. The Mann–Whitney *U* test or Kruskal-Wallis test was used for variables that do not satisfy the assumption of homogeneity of variance. The 10 self-designed questions, anxiety, and resilience scores exhibited a non-normal distribution, as indicated by the Shapiro–Wilk test ($p < 0.05$). Additionally, the corresponding Cronbach's α coefficients were calculated. Spearman's correlation analysis was used to evaluate the relationships among the self-designed questions, resilience, and anxiety.

Using the bootstrap-mediated effects test, we hypothesized that resilience mediated between self-imposed questions and anxiety. Therefore, the non-parametric percentile bootstrap method was used to test the mediating effect of resilience between self-designed questions and anxiety ($N = 5{,}000$) (24, 25). The mediating effect analysis aims to determine the presence of a mediating effect and identify the corresponding parameter type. The significance of the parameter refers to the value of the influence effect. A mediating effect is considered statistically significant when the 95% confidence interval of bootstrap does not include 0 (38). A mediated effect path analysis diagram was produced using Amos 23.0 modeling and analysis. All statistical tests were two-tailed, and *p*-values < 0.05 were considered statistically significant.

Trustworthiness

We took measures to ensure the credibility of this study, as elaborated in our previous research. These measures included (1) the research team comprised individuals with expertise in conducting mixed-methods, qualitative, or quantitative studies; (2) the principal investigator remained in frequent communication with methodological experts to address challenges in the research process continually; (3) participants validated the findings upon analyzing qualitative data to ensure consistency; and (4) the study adhered strictly to operational procedures throughout its execution.

Results

Demographic characteristics

The qualitative study had 20 participants with an average age of 34.47 ± 7.47 years, 75% women, and an average work experience of 9.73 ± 8.85 years. The quantitative study had 210 participants with a mean age of 36.62 ± 8.24 years, 75.24% female, and a mean work experience of 13.55 ± 9.55 years. Demographic data are shown in Table 1.

Qualitative results

The qualitative study results were divided into three parts: pharmacist psychological status under quarantine, factors influencing pharmacist psychological status, and countermeasures against negative psychological states under quarantine.

Psychological states of pharmacists under quarantine

The psychological state of the HQHPs under quarantine was identified (Table 2). The participants stated that compared to late 2019, HQHPs had gradually adapted to the impact of the epidemic and quarantine, and their mentality was more stable. However, there were still various factors that caused negative emotions, such as anxiety. After 3 years of the epidemic, HQHPs had gained a lot of experience that could help them to alleviate negative emotions. In the quarantined situation, some participants also mentioned that they reflected on life and felt that the value of life had been sublimated.

Multidimensional factors affecting the psychological state of HQHPs

Two main themes were identified regarding the factors influencing the HQHPs' mental health (Table 3). Among them, positive factors

TABLE 3 Factors affecting the mental health of HQHPs.

(Sub-)themes	Quotations
1 Positive factors	
1.1 Personal factors	
Good physical state	*I feel that my body is healthy, my immune system is fine, and that's important (G2P1).*
Optimism	*I feel like I'm always optimistic (P2).*
	I think I have an acceptable personality and am relatively optimistic (P7).
	I am a relatively optimistic person (P3, P6, P8).
1.2 Supportive interpersonal relationships	
The company of family	*Chat with family members* via *telephone/video can help ease my anxiety (P2).*
	My parents are relatively positive people, they will comfort you that it is impossible to stay at home because of the epidemic now, let us relax and do not have economic pressure (P6).
	Because of the pandemic, I could spend more time with children and communicate with them, which could help them and myself relieve negative emotions (P7).
Connection with friends	*I would talk to my friends, and as a medical professional myself, I felt it was my duty and responsibility to enlighten them or lead them in a positive direction (P8).*
Support from colleagues	*Because I think most of my colleagues are quite optimistic when it comes to this kind of thing, and although it is true that some of them may not be able to adapt for a period of time, we all encourage each other and enlighten each other, and I feel that this overall atmosphere is still manageable (G1P2).*
1.3 Harmonious environment	
Family environment	*After so much experience, I feel that the family's mentality is more peaceful, and the environment of our family is still relatively harmonious during this period (G2P3).*
2 Negative factors	
2.1 Unreasonable community defense measures	*The mood is still affected differently by different levels of management in the community. I think the policies in our neighborhood are too strict and affect normal life (G1P1).*
	The community told me to sign a letter of commitment，that I could go out and then not be allowed to come back. However, I have two small children at home, so if I go to work and am not allowed to come home, the impact will definitely be great, and I think this policy is unreasonable (G2P1).
2.2 Inadequate supplies	*Inadequate basic supplies (e.g., food, water) during quarantine was a source of anxiety (P3).*
2.3 Unreasonable anti-epidemic policies	*The epidemic lockdown is one-size-fits-all, and the duration of lockdown is unclear, making it impossible for health workers to participate in front-line work (P4).*
2.4 Unscientific management of public opinion	*The current epidemic prevention policy, anyway, is not very transparent, and people do not get enough information about the social side of the community, and they do not get effective feedback, so it creates a sense of fear (G1P2).*
	This round of epidemic information has not been released in an open, transparent, and timely manner (P1,P3,P4,P8).
	Because the official information is not timely, the public opinion on the internet cannot distinguish between true and false (P2,P5).
	There are some flaws in this information disclosure, which then leads to more rumors and then a strong sense of panic among people (G2P2).
2.5 Other emergencies	*Because I work in the hospital pharmacy, relatives in my family often entrust me with the purchase of medicines. Some people have special conditions that prevent them from cutting off their medication. But because of this period of closure, it would not be possible to get their medication in time, and this matter would cause me a little distress (P4).*
	My child has serious constipation recently, and I cannot take him out to see a doctor, and then my family has a lot of arguments because of his constipation (P5).

include (1) personal factors, such as good physical state and optimism; (2) supportive interpersonal relationships, such as family companion, connection with friends, and colleague support; and (3) harmonious environment, for example, a family environment. The negative factors include: (1) community defense measures deemed unreasonable, (2) insufficient supplies, (3) anti-epidemic policies perceived as inadequate, (4) unscientific management of public opinion, including opaque information and low credibility of self-media, and (5) other unforeseen emergencies.

Strategies for coping with psychological problems under quarantine

The strategies to cope with psychological problems fell into five broad categories (Table 4). Most of the participants highlighted exercise, such as yoga, as a stress-relief method. Interacting with family or friends was also cited as a mood-enhancing activity. The participation in simple household tasks such as cooking, in addition to participating in personal favorite recreational activities such as

watching movies or listening to music, were identified as effective coping strategies. Lastly, involving oneself in work-related tasks to maintain a productive state was mentioned as a means to alleviate negative emotions.

Quantitative results

In the quantitative part of the study, we implemented a 10-item additional survey based on the qualitative research that defined the role of personal factors, interpersonal relationships, the surrounding environment, community management, epidemic prevention policies, and public opinion management in influencing HQHPs' mental health (Figure 2). We also used GAD-7 and CD-RISC by a web-based questionnaire to investigate the mental health status of hospital pharmacists. Cronbach's alpha indicates relatively high internal reliability for the three parts of the questionnaire (Cronbach's $\alpha = 0.839$ for the 10 self-designed questions, $\alpha = 0.963$ for the Chinese version of CD-RISC-25, and $\alpha = 0.929$ for GAD-7), indicating good reliability of questionnaires in quantitative studies.

We used the Kaiser-Meyer-Olkin (KMO) index to determine if the data were suitable for factor analysis (26). The value of KMO was 0.839, which is above the threshold of 0.7. To facilitate subsequent studies, we conducted an exploratory factor analysis (EFA) on the 10 self-designed questions. EFA revealed two factors with a cumulative explained variance of 65.896%, where Q1-Q6 had higher scores, and this higher level of agreement represents a positive personal state or surrounding environment, thus defining them as positive factors. Whereas, Q7–Q10 had relatively lower scores and lower levels of agreement showed a negative external environment, thus defining them as negative factors (Supplementary Table S4).

Mental health status of HQHPs

CD-RISC-25 scores for HQHPs ranged from 23 to 100, with a median score of 66 [55.75, 74], which is in the range of low resilience. As shown in Supplementary Table S5, the resilience was significantly higher in the male group than in the female group ($p = 0.006$). There were no significant differences in other demographic variables. In terms of anxiety, the median GAD-7 score was 5 [2, 7], which is on the mild anxiety level. There were no significant differences in anxiety scores between all demographic variables.

HQHPs' evaluation of impact factors

The findings indicated that 80% of HQHPs affirmed being in good physical condition and sufficiently resilient at the physiological level to cope with the impacts of epidemic containment. A substantial majority (80% or more) of HQHPs reported having a harmonious family living environment supported by family members, friends, and colleagues. However, only 46.34% expressed strong optimism, 21.14% did not consider themselves naturally optimistic, and 32.52% had reservations. Furthermore, the HQHPs expressed concerns about the perceived lack of preventive and control measures at the scientific level and deemed government-level prevention and control policies unreasonable. The management of public opinion at the social level could have been more transparent, with only 38.57%, 45.70%, and 27.62% of the respondents agreeing with the reasonableness of these three aspects, respectively. In particular, a small percentage of HQHPs (7.53%) reported having strong religious beliefs. Detailed quantitative findings are presented in Figure 2.

Correlation analysis of self-designed questions, resilience, and anxiety

The Shapiro–Wilk test showed that the data conform to nonnormality. Spearman's correlation analysis showed that positive factors (Q1–Q6) and negative factors (Q7–Q10) were all positively correlated with CD-RISC-25 scores and negatively correlated with the GAD-7 score. There was a significant negative correlation between resilience and anxiety (Spearman correlation $r = -0.451$, $p < 0.001$; Supplementary Table S6).

The mediating effect of psychological resilience

Following mediating effects analysis, for positive factors (Q1–Q6), the total and indirect effects on anxiety were significant ($p < 0.01$), with a mediating effect confidence interval of [−1.818, −0.384] (Table 5). The indirect impact accounted for 39.01%, indicating partial mediation by resilience. Similarly, for negative factors (Q7–Q10), total and indirect effects on anxiety were significant ($p < 0.01$), with a mediating effect confidence interval of [−1.174, −0.430] (Table 6). Resilience played a partial mediating role, representing 82.87% of the total effect, while the direct effect of negative factors on anxiety was non-significant ($p > 0.05$).

Amos was used to construct a structural equation model, with resilience serving as a mediator variable (Figure 3). Regarding positive factors (Q1–Q6), the results indicated that the path coefficients in the model were statistically significant ($p < 0.01$), and the fit indices for the structural equation model were as follows: CMIN/DF = 3.524, RMSEA = 0.110. Specifically, Q7–Q10 demonstrated a positive impact on resilience ($\beta = 0.58$, $p < 0.01$), while resilience showed a negative effect on anxiety ($\beta = -0.32$, $p < 0.01$). Concerning negative factors, the path coefficient of the model was also statistically significant ($p < 0.01$), and the fit indices were deemed acceptable: CMIN/DF = 2.111, RMSEA = 0.073. In particular, Q7–Q10 showed a positive influence on resilience ($\beta = 0.47$, $p < 0.01$), and resilience had a negative effect on anxiety ($\beta = -0.39$, $p < 0.01$).

Discussion

This study is one of the few mixed-method investigations to examine the mental health challenges faced by HQHPs in the later stages of the COVID-19 pandemic. The unique circumstances encountered by the participants can be attributed to several factors: (1) they remained under home quarantine for up to 2 weeks even after quarantine measures were lifted globally; (2) the study city, Zhengzhou, being a megacity, faced challenges in the supply of essential living materials during the quarantine period (27, 39); (3) unlike prior quarantines where medical personnel, including hospital

TABLE 4 Coping strategies.

Themes	Quotations
Exercise	*Coping strategies for me is exercise, read a book, listen to music, or making food (P1).*
	Following Tik Tok to do fat loss exercises, or other exercises, is a very important way to vent emotions (G3P4).
Interpersonal interaction	*The main way to relieve anxiety is through family activities, such as playing games with children (P2).*
	We can communicate with friends by video, and I also drink with my friends by video, which is quite relaxing (G1P2).
	Video chat with other brothers to have a heart to heart talk (G1P4).
	There are so many things that we can play with, and even though I'm at home isolation, I have not lost touch with my friends, and that's one of the things that makes me happy. Modern technological advances have allowed us to play together even when we are not together (G3P2).
Do the housework	*Do the housework, tidy up the clothes, do the cooking, I think that's pretty good too (G2P2).*
Entertainment	*For me, listen to music, watch films, and playing with children are the way to ease (P5).*
	Dancing at home, singing, and watching some funny films with my family, I think it's great to watch films where everyone laughs and has fun and it's a way to lighten the mood (G3P2).
	When I take a break, I read something I like, then listen to music, occasionally watch a film, it's all very relaxing (G2P1).
Maintaining working conditions	*Doing something related to work at home, like reading the literature, can distract me from anxiety and confusion (P4).*

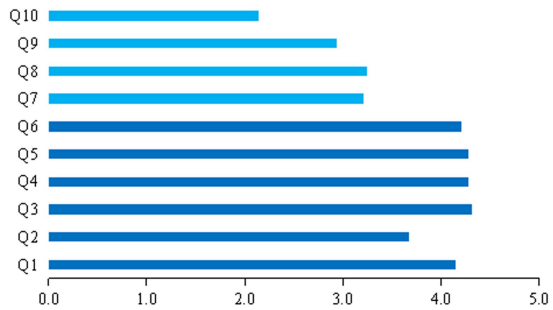

FIGURE 2
Evaluation of HQHPs on impact factors. Q1: I think my body state enough to deal with in the past few days; Q2: I think I'm naturally optimistic; Q3: I feel very supported by my family; Q4: I think my friends are very supportive; Q5: I get along well with my coworkers; Q6: I think my family environment is very harmonious; Q7: I think the epidemic prevention management in the community is very scientific; Q8: I think the epidemic prevention and control policies are very scientific; Q9: I think the public opinions on epidemic prevention and control are full of positive energy; Q10: I have a stronger religious faith.

pharmacists, were allowed to move freely with work permits, this time they were subjected to strict restrictions; and (4) despite the crucial role pharmacists play in epidemic prevention and control, their contributions were occasionally overlooked (13). Consequently, we believe that the findings of this study contribute valuable information to a broader understanding of the mental health of medical staff in the context of pandemics like COVID-19.

The qualitative research findings shed light on the impact of home isolation on the mental well-being of hospital pharmacists and offer an initial exploration of the coping measures they employ. The factors influencing home quarantine on the mental health of HQHPs were identified and categorized into positive and negative factors. The positive factors were optimism, family companionship, and connections with friends. These findings are consistent with existing research, highlighting the role of personal resources such as optimism, prosocial behavior, and resilience in effectively mitigating the adverse consequences of the pandemic on mental health (40–42). In addition, the importance of family companionship and connections with friends in alleviating mental stress has also been affirmed in other studies (43, 44).

Negative factors include insufficient supplies, inadequate information, and other emergent situations. The substantial impact of scarce basic supplies on psychological distress has been well-documented in previous studies (45). In response, relevant government departments must ensure that quarantined households have ample supplies to meet basic needs, delivered promptly, and ideally coordinated in advance with conservation and redistribution plans to prevent resource depletion.

Since the onset of COVID-19, there has been increased demand and attention for pandemic-related information. Information reception generally falls into two categories: official and unofficial sources. Official sources involve government disclosures and expert voices in medical and other fields. Unofficial sources include Internet users' opinions, gossip, and conversations with family and friends, both online (e.g., WeChat, phone calls) and offline (face-to-face). In this study, numerous participants indicated dissatisfaction with the official release of information, causing a reliance on social media for information, which may contain misinformation and disinformation detrimental to physical and mental health. In line with WHO recommendations, member states should develop action plans to manage the infodemic by promoting the timely dissemination of accurate information based on science and evidence, particularly to high-risk groups, while combating misinformation and respecting freedom of expression (46). HQHPs in quarantine may also be concerned about staff shortages that cause additional work for colleagues. Other emergencies, such as difficulty accessing regular medical care and prescriptions, emerged as challenges for some participants.

In the second stage, GAD-7 and CD-RISC-25 were used to assess the mental health levels (anxiety and resilience) of HQHPs. The results revealed that the HQHPs exhibited mild anxiety levels and resilience scores within the range of low resilience. In particular, at the time of the study, the epidemic had persisted for nearly 3 years. On the one

TABLE 5 The mediating effect of resilience between positive factors and anxiety.

Path	(Effect)	(SE)	LLCI (95%)	ULCI (95%)	t (p)	Effect value (%)
a:PF → RES	15.51	1.286	12.979	18.048	12.07 (<0.001)	
b:RES → ANX	−0.07	0.019	−0.104	−0.029	−3.49 (<0.001)	
c:PF → ANX (total effect)	−2.64	0.363	−3.362	−1.932	−7.30 (<0.001)	
d:PF → RES → ANX (indirect effect)	−1.03	0.367	−1.818	−0.384		39.01
e:PF → ANX (direct effect)	−1.62	0.461	−2.525	−0.708		61.36

PF, Positive Factors; RES, Resilience; ANX, Anxiety; LLCI (95%), Lower level of the 95% confidence interval; ULCI (95%), Upper level of the 95% confidence interval.

TABLE 6 The mediating effect of resilience between negative factors and anxiety.

Path	(Effect)	(SE)	LLCI (95%)	ULCI (95%)	t (*p*)	Effect value (%)
a:NF → RES	7.25	1.042	5.199	9.308	9.41 (<0.001)	
b: RES → ANX	−0.11	0.017	−0.138	−0.072	−5.29 (<0.001)	
c:NF → ANX (total effect)	−0.92	0.273	−1.461	−0.384	−4.95 (<0.001)	
d:NF → RES → ANX (indirect effect)	−0.761	0.192	−1.174	−0.430		82.72
e: NF → ANX (direct effect)	−0.16	0.279	−0.709	−0.709		17.39

NF, Negative Factors; RES, Resilience; ANX, Anxiety; LLCI (95%), Lower level of the 95% confidence interval; ULCI (95%), Upper level of the 95% confidence interval.

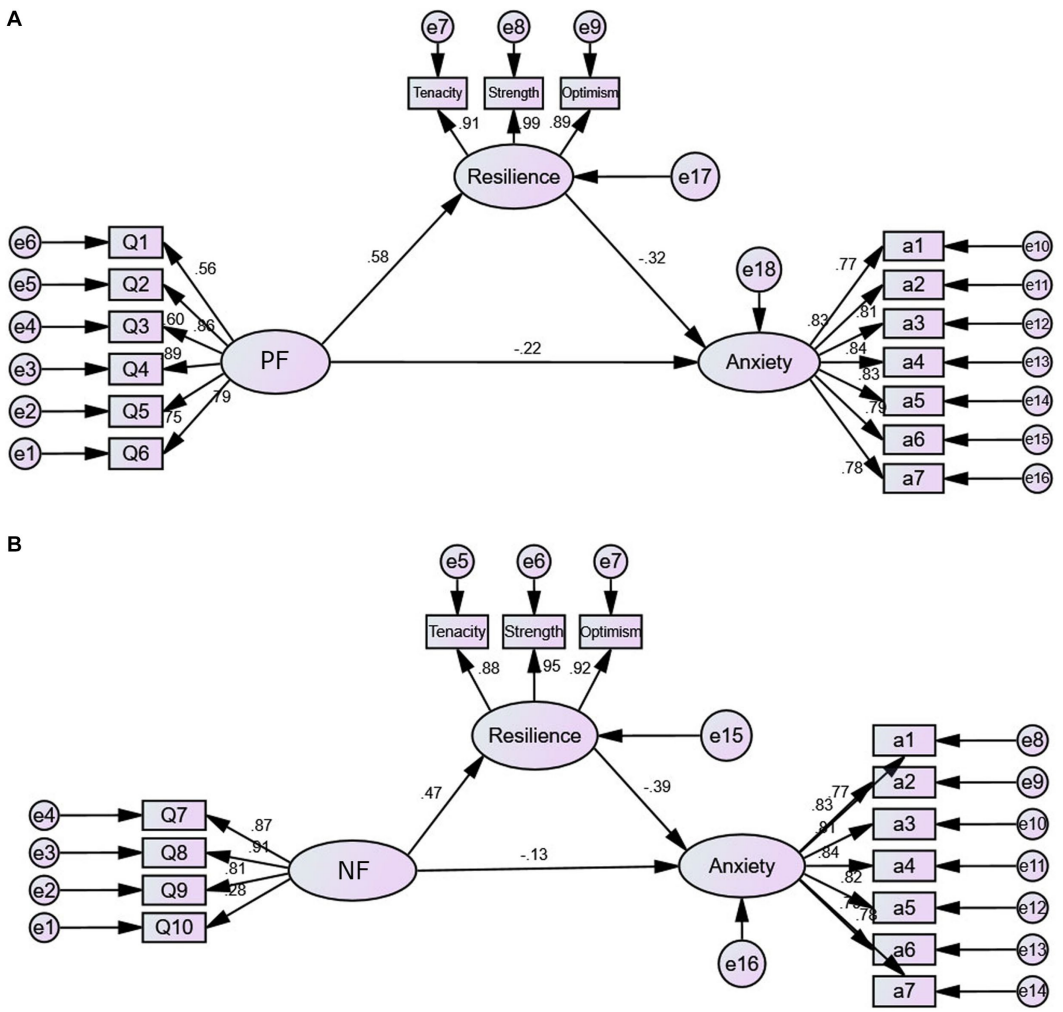

FIGURE 3
A mediating model of resilience between positive factors **(A)**, negative factors **(B)** and anxiety. PF, Positive factors; NF, Negative factors.

hand, the public's attitude toward the epidemic had evolved from initial panic and anxiety to adaptation and acceptance, resulting in generally mild anxiety levels among HQHPs (47). However, multiple sporadic cases and local outbreaks, coupled with uncertainty about when the outbreak would end, contributed to a reduction in the psychological resilience of the public (40). At this stage, we explored the correlations between the influencing factors identified in the first stage and the levels of resilience and anxiety. The results confirmed that, except for religious belief, the other factors were positively and negatively correlated with resilience and anxiety, respectively. These findings have significant value in preventing and reducing psychological issues among pharmacists.

This study has several strengths and weaknesses. Strengths include enhancing knowledge of hospital pharmacists' psychological state post-epidemic, a specific and representative target population and scenario, and using an embedded mixed methods approach for robust results. However, weaknesses include a relatively small quantitative sample size, a need for in-depth exploration of resilience mediating effects, a limited geographic scope to one province in central China, and the potential for subjective biases in data interpretation. Researchers should exercise caution, ensuring transparency in their methodology to mitigate these limitations.

Conclusion

Our study reveals significant correlations between the psychological resilience and anxiety of HQHPs and their traits, the micro-environment of survival, and the macro-environment. Except for religious beliefs, all first-stage influencing factors are positively correlated with CD-RISC-25 and negatively correlated with GAD-7. This underscores the importance of maintaining positive relationships with family and friends during home sequestration in the face of public health emergencies. Furthermore, our research explores coping strategies used by HQHPs to alleviate anxiety during stay-at-home conditions, such as exercise, yoga, watching films, listening to music, cooking, and playing with children. These findings offer insight into safeguarding the psychological well-being of healthcare workers in future public health emergencies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethics was approved by the First Affiliated Hospital of Zhengzhou University Institutional Review Board (No. 2022-KY-0736). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

ZY: Investigation, Methodology, Writing – original draft, Writing – review & editing. XW: Data curation, Investigation, Writing – original draft. XL: Data curation, Investigation, Writing – original draft. HF: Funding acquisition, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1268638/full#supplementary-material

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Explaining differences in self-focused and other-involved public health preventive behaviors between the US and China: the role of self- construal and health locus of control

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Background: This study examined national similarities and differences in people's engagement in health preventive behaviors during a public health crisis, as well as investigated the underlying individual-level psychological mechanisms. A conceptual distinction was made between self-focused and other-involved preventive behaviors in response to public health crises.

Method: Two cross-sectional surveys were conducted in the United States ($N = 888$) and China ($N = 844$) during the early stage of the COVID-19 pandemic. Hayes' PROCESS was utilized to assess national differences in seven preventive behaviors, along with the mediating effects of self-construal and health locus of control.

Results: The results showed that American participants reported greater engagement in self-focused preventive behaviors than Chinese, whereas Chinese participants reported greater engagement in other-involved preventive behaviors than Americans. Chinese participants also engaged more in other-involved than self-focused preventive behaviors. Self-construal and health locus of control partially explained the observed differences in engagement in preventive behaviors.

Discussion: This study introduces a culture-sensitive approach to provide insights for crafting communication interventions that can enhance the effectiveness of health campaigns in the context of a public health crisis.

KEYWORDS

health locus of control, health intervention, public health, self-construal, cultural differences

1 Introduction

Over the past century, the world has been witnessing several waves of public health crises, with the recent coronavirus disease (COVID-19) being one of the most prominent one in human history (1). The battle against this public health crisis has revealed national differences in both the impact of the virus and approaches to dealing with it. For example, countries that are conventionally considered individualist societies tend to have more

COVID-19 cases than collectivist societies (2). People from countries with a culture less tolerant of uncertainty and ambiguity also tend to have fewer social gatherings, which might have helped control a public health crisis in those countries (3).

Although the abovementioned studies explain the national differences through national cultures, it is crucial to investigate individual-level psychological mechanisms to guide behavioral interventions and communication campaigns in tackling a public health crisis. This study addresses such mechanisms by surveying people who lived in the United States and China during the pandemic regarding their engagement in preventive behaviors against the COVID-19 pandemic. Public crises, such as the pandemic, often present both independent, individual risks and interdependent, communal risks, thus requiring not only self-protection but also collective actions of a larger community (4). In response to both individual and communal risks, we first distinguish between two types of preventive behaviors: *self-focused* and *other-involved* preventive behaviors. The former refers to preventive behaviors performed in private settings, while the latter highlights the interdependence among individuals as such preventive behaviors require social monitoring or cooperation from others. Examining these two types of preventive behaviors helps us understand individual actions in relation to others and better tap into the communal nature of most public health crises.

To illuminate the psychological mechanisms underlying self-focused and other-involved preventive behaviors, we further investigate two culturally linked psychological traits: self-construal and health locus of control. Self-construal refers to the extent to which individuals see themselves as independent or interdependent in relation to others and is a relatively stable aspect of an individual's identity (5). Health locus of control refers to how people attribute responsibilities for their health to internal factors, powerful others, and chance (6). In the context of the current study, we specifically explore whether people believe that their health during the pandemic is controlled by their own actions, such as wearing masks or social distancing (i.e., internal factors), by health authorities or government mandates (i.e., powerful others), or by chance. As will be discussed later, both self-construal and health locus of control are highly influenced by culture. They not only help explain the national differences in self-focused and other-involved preventive behaviors but also provide guidance for designing personalized health interventions.

In brief, the objective of this study is to examine similarities and differences between American and Chinese people's engagement in self-focused and other-involved public health preventive behaviors. To achieve this goal, we first explicate the two types of preventive behaviors and discuss how engagement in these behaviors might differ between Americans and Chinese. We then explore how self-construal and health locus of control account for the national differences in engagement in the two types of preventive behaviors. Next, we report a survey study designed to investigate our hypotheses. Implications of the findings are discussed in relation to global recovery and health interventions aimed at combating a public health crisis.

2 Literature review

2.1 A categorization of preventive behaviors during a public health crisis

Previous research highlights how specific preventive behaviors during a public health crisis differ across nations (e.g., wearing masks; (7), yet it overlooks the similarities and differences across various health preventive behaviors. We argue that preventive behaviors can be theoretically categorized as either *self-focused* or *other-involved*. Self-focused preventive behaviors are those that are often performed in relatively private settings that involve minimal monitoring, social interaction, or cooperation from others. Washing hands and disinfecting surfaces, as recommended by the Centers for Disease Control and Prevention (CDC) in both China and the United States, are examples of self-focused preventive behaviors. In contrast, other-involved preventive behaviors are typically performed in public settings and can be easily observed and monitored by the public. The effectiveness of other-involved preventive behaviors also depends on others' cooperation and implies a need to understand a public health crisis as an interdependent, communal risk. Seen in this light, wearing a mask (typically performed in a social setting), covering nose and mouth when sneezing and coughing, keeping social distance, staying home (the opposite of going outside), and avoiding public transportation (the opposite of taking public transportation) can all be considered other-involved preventive behaviors.

While the abovementioned preventive behaviors all serve the purpose of preventing the transmission of the disease, societies with different cultural backgrounds may exhibit different acceptance of self-focused or other-involved preventive behaviors. In particularly, individualistic societies may favor self-focused preventive behaviors over other-involved behaviors because individualistic cultures typically endorse personal choice and individual interest (8). Self-focused behaviors, in essence, protect one's own vital interests, whereas the other-involved behaviors likely impose constraints on one's autonomy. Similarly, collectivist societies value collective interests and social norms (8) and thus are likely to encourage other-involved preventive behaviors more than self-focused preventive behaviors. Given that the United States and China are conventionally considered individualist and collectivist societies, respectively (9), we postulate that people from these two societies would engage differently in the two types of preventive behaviors. These differences should be manifested both between the two nations and within each of them, as postulated below.

H1a: Compared to the Chinese, Americans will be more frequently engaged in self-focused preventive behaviors (e.g., washing hands and disinfecting surfaces).

H1b: Compared to Americans, Chinese will be more frequently engaged in other-involved preventive behaviors (e.g., wearing a mask, covering nose and mouth when sneezing and coughing, keeping social distance, staying home, and avoiding public transportation).

H2a: Americans will be more frequently engaged in self-focused preventive behaviors than other-involved preventive behaviors on average.

H2b: Chinese will be more frequently engaged in other-involved preventive behaviors than self-focused preventive behaviors on average.

2.2 Psychological traits and preventive behaviors

While differences in self-focused and other-involved preventive behaviors can exist at the national level, both between and within the United States and China, we need to delve into the underlying individual-level psychological mechanisms to inform potential behavioral interventions and communication campaigns. As discussed in the following paragraph, two psychological traits—self-construal and health locus of control—are especially relevant.

2.2.1 Self-construal and preventive behaviors

Self-construal is defined as "a constellation of thoughts, feelings, and actions concerning one's relationship to others, and the self as distinct from others" [(10), p. 581]. Prior research has documented two major forms of self-construal: independent and interdependent self-construal (5). An independent self-construal views the self as an autonomous person (5). Individuals with an independent self-construal tend to consider their personal desires, preferences, attributes, and abilities central and important to their own identities. In contrast, an interdependent self-construal defines the self as a flexible and variable unit that emphasizes connections with others and social contexts (10). Individuals with an interdependent self-construal tend to act more based on the expectations of others and social norms than their personal desires (11).

In the context of a public health crisis, independent and interdependent self-construal likely play different roles in an individual's engagement in self-focused and other-involved preventive behaviors. Research shows that people from China typically score higher in measures of interdependent self-construal, whereas people from the United States tend to score higher in independent self-construal (12, 13). Being more relationship-concerning and norm-abiding, people with an interdependent self-construal could be more motivated to engage in other-involved preventive behaviors, because such behaviors are likely to be perceived as a part of the collective efforts to battle infectious diseases that spread across a community. However, interdependent self-construal does not necessarily preclude self-focused preventive behaviors, as such behaviors may be perceived as protecting both themselves and others due to the awareness of the communal risks in a public health crisis and the interdependence between self and others. Therefore, we expect interdependent self-construal to have a positive impact on engagement in both self-focused and other-involved preventive behaviors.

H3: Individuals' interdependent self-construal will be positively associated with their engagement in (a) self-focused preventive behaviors and (b) other-involved preventive behaviors.

Independent self-construal may influence engagement in preventive behaviors differently. Individuals with high independent self-construal focus on autonomy and prioritize personal goals over group goals (11). Thus, they may be more motivated toward self-focused preventive behaviors, which closely align with their own interests. In contrast, other-involved preventive behaviors entail concerns over others' interests and sometimes may work against one's self-interest. For instance, staying home could protect oneself and others from infections, but this action also restricts one's freedom of movement and can cause inconveniences. Supporting this idea, research has found that people with a high degree of independent self-construal were less interested in keeping social distance (14) and climate-friendly actions that involve personal sacrifice (15), which are both other-involved preventive behaviors. Therefore, we expect independent self-construal to impact self-focused and other-involved preventive behaviors in opposing ways, as postulated below.

H4: Individuals' independent self-construal will be (a) positively associated with their engagement in self-focused preventive behaviors but (b) negatively associated with their engagement in other-involved preventive behaviors.

2.2.2 Health locus of control and preventive behaviors

People from different countries may also vary in their health locus of control and, consequently, their engagement in self-focused and other-involved preventive behaviors. The concept of health locus of control can be traced back to Rotter (16) social learning theory, which differentiates individuals' attribution of a certain behavior to internal factors (i.e., events that are consequences of individuals' own actions) and external factors (i.e., events that are unrelated to individuals' actions). With respect to health-related behaviors, Wallston et al. (17) argue that the twofold conceptualization can be elaborated as follows: in addition to control by internal factors (i.e., health is the result of one's own actions), control by external factors can be further divided into two subcategories: control by powerful others (e.g., doctors, physicians, and health institutions) and control by chance (i.e., health is due to fate or chance).

Different dimensions of national culture (9) can influence the three loci of control. Regarding control by internal factors, people from individualist societies are more likely to perceive themselves as having control over their health compared to those from collectivist societies (18, 19), which is partly because individualistic countries value self-reliance and react strongly to a loss of personal control (20). For control by powerful others, another cultural dimension—power distance—is highly relevant. Power distance is "the extent to which the less powerful members of organizations and institutions accept and expect that power is distributed unequally" [(21), p. 9]. Countries with higher levels of perceived power distance tend to view control by powerful others or authority figures as more acceptable or positive (20). In public health contexts, the most relevant powerful others are health authorities, and therefore, a culture with high power distance

may enhance its people's sense of health locus of control by these authorities (22). Finally, with respect to control by chance, the cultural dimension of indulgence is relevant. Indulgence (vs. restraint) refers to the gratification vs. control of the basic human desires to enjoy life (21). Individuals from indulgence-oriented societies tend to place greater importance on leisure and live an unrestrained and pleasure-seeking lifestyle; in contrast, individuals from restraint-oriented societies tend to view leisure as less important and restrain from hedonic lifestyles (23). Accordingly, research has shown that people living in restraint-oriented societies tend to pay more attention to their health [e.g., choosing healthier meals; (20)], irrespective of societal economic development. In contrast, people from indulgence-oriented societies tend to engage more in smoking and are less likely to adopt a healthy diet (20), suggesting that they are more likely to leave their health to chance or fate.

The United States and China are usually positioned at the opposite ends of the spectrums for the three cultural dimensions mentioned above (21). The United States is generally characterized by high individualism, low power distance, and indulgent lifestyles, while China exhibits high collectivism, high power distance, and restrained lifestyles. Accordingly, we expect that Americans and Chinese would differ in the three types of health locus of control, as postulated below.

> H5: Americans will perceive a higher level of health locus control by (a) internal factors and (b) chance but a lower level of control by (c) powerful others compared to Chinese.

At the individual level, the three types of health locus of control then differently influence the self-focused and other-involved preventive behaviors. In terms of control by powerful others, previous research has consistently found that this health locus of control promotes compliance with health authorities (24). For example, patients tend to engage in health monitoring behaviors due to the fear of violating their doctors' recommendations (6). College students also show more willingness to use health apps and online trackers (25) and to reduce drug use due to their compliance with directives from health authorities (26). Because both self-focused and other-involved preventive behaviors are typically recommended by public health authorities, for example, the CDC guidance for COVID-19 prevention in the United States and China, we expect people with high levels of control by powerful others to comply with both types of preventive behaviors, as postulated below.

> H6: Individuals' perceived health locus of control by powerful others will be positively associated with their engagement in (a) self-focused and (b) other-involved preventive behaviors.

With respect to control by chance, this health locus of control generally reduces people's engagement in preventive behaviors (17). Such a sense implies that a person's health depends on fate or chance, thus reducing the motivation to exert control over one's own health. The sense of control by chance was even found to encourage health-threatening behaviors, such as smoking, alcohol consumption, drug use, and avoiding a healthy diet (20, 26). In a public health crisis, where both self-focused and other-involved preventive behaviors would concern one's own health and require control over one's own behaviors, we expect people with higher levels of control by chance to be less likely to engage in either type of preventive behaviors, as postulated below.

> H7: Individuals' health locus of control by chance will be negatively associated with their engagement in (a) self-focused and (b) other-involved preventive behaviors.

Finally, regarding control by internal factors, we argue that it can promote self-focused preventive behaviors but discourage other-focused preventive behaviors, in contrast to the uniformly positive or negative effects of the other two types of health locus control. By definition, control by internal factors entails a belief in one's self-control over their health condition (6). Such self-control is required for self-focused preventive behaviors, as they are performed in private settings that involve minimal monitoring from others. Therefore, a greater sense of control by internal factors will better motivate self-focused preventive behaviors. At the same time, individuals with a greater sense of health locus of control by internal factors often pay closer attention to their own health condition (6) and thus are more likely to engage in self-focused preventive behaviors, thereby protecting themselves (e.g., HIV preventive behaviors, (27); health-promoting prenatal behaviors, (28); dental care, smoking cessation, and flu shot, (6).

However, the sense of control by internal factors may discourage other-involved preventive behaviors. The theory of planned behavior (29) suggests that the successful adoption of a healthy behavior requires individuals to have perceived control over the recommended behavior. When the efficiency of the recommended behaviors depends on the implementation by not only oneself but also others, as in the case of other-involved preventive behaviors, people will consider themselves to have less control (over others' behaviors) and thus be less motivated to perform these recommended behaviors. Moreover, as mentioned above, individuals with higher levels of health locus of control by internal factors typically focus on their own health conditions (6). Given a person's limited cognitive resources, these individuals are likely to be preoccupied with attention to their own health conditions and self-focused preventive behaviors, leaving other-involved preventive behaviors to be less attended to.

Taken together, we hypothesize that the health locus of control by internal factors has opposite effects on the two types of preventive behaviors, as follows.

> H8: Individuals' health locus of control by internal factors will be (a) positively associated with their engagement in self-focused preventive behaviors but (b) negatively associated with their engagement in other-involved preventive behaviors.

3 Methods

3.1 Participants and procedure

This study surveyed people (above 18 years old) from both the United States ($N = 888$; 47.5% female participants; 18–74 years

old, $M = 37.00$, $SD = 11.94$) and China ($N = 844$; 55.6% female participants;18–64 years old, $M = 31.71$, $SD = 8.40$) in April 2020. Participants in the United States were recruited from Amazon Mechanical Turk (https://mturk.com) and were paid USD$ 0.75 each, while Chinese participants were recruited from Sojump (wjx.cn) and were each paid RMB¥ 3.5 (Chinese yuan, roughly the same as the amount paid to American participants based on currency rate).

We constructed the questionnaire first in English and then translated it into Chinese. To ensure the accuracy and appropriateness of the translation, a research assistant who is proficient in both English and Chinese independently back-translated the Chinese questionnaire into English. The research assistant did not read the English version before conducting the translation. The back-translated version was then compared with the English version, and any deviation in meanings was addressed by revising and re-translating the Chinese questionnaire (see Supplementary Table S3 for the final questionnaire items in both languages).

3.2 Measures

3.2.1 Engagement in preventive behaviors

We measured seven preventive behaviors recommended by the WHO and the CDC in both the United States and China, using a 5-point scale (*1 = never, 2 = sometimes, 3 = about half the time, 4 = most of the time, and 5 = always*). For the American sample, the items were prefaced with the question "[o]ver the past month [i.e., March 2020], how often have you engaged in the following practices to minimize the risk of contracting the coronavirus (COVID-19)?" Since the outbreak was first identified in China and the infected cases peaked around February 2020, we prefaced the same items with "[d]uring February this year," for the Chinese sample.

Two preventive behaviors are considered as *self-focused*, namely, "washing hands" ($M_{US} = 4.34$, $SD_{US} = 0.90$; $M_{China} = 4.11$, and $SD_{China} = 0.84$) and "cleaning and disinfecting frequently touched surfaces" ($M_{US} = 4.01$, $SD_{US} = 1.06$; $M_{China} = 3.56$, and $SD_{China} = 1.15$). The other five preventive behaviors are *other-involved*, namely, "wearing face masks" ($M_{US} = 3.38$, $SD_{US} = 1.49$; $M_{China} = 4.88$, $SD_{China} = 0.41$), "covering nose and mouth when sneezing and coughing" ($M_{US} = 4.38$, $SD_{US} = 0.91$; $M_{China} = 4.37$, $SD_{China} = 0.81$), "keeping social distance" ($M_{US} = 4.33$, $SD_{US} = 0.87$; $M_{China} = 4.51$, $SD_{China} = 0.68$), "staying home" ($M_{US} = 4.18$, $SD_{US} = 0.85$; $M_{China} = 4.39$, $SD_{China} = 0.69$), and "avoiding public transportation" ($M_{US} = 4.51$, $SD_{US} = 0.85$; $M_{China} = 4.42$, $SD_{China} = 0.88$).

3.2.2 Independent and interdependent self-construal

Participants' independent and interdependent self-construal were measured using a simplified version of the self-construal scale (12) on a 7-point Likert scale (*1 = strongly disagree; 7 = strongly agree*). The subscale for independent self-construal includes five items, such as, "[m]y personal identity, independent from others, is important to me" and "I prefer to be self-reliant rather than dependent on others." The average scale score was 5.44 ($SD = 0.93$ and Cronbach's $\alpha = 0.84$) in the American sample and 5.28 ($SD = 0.91$ and Cronbach's $\alpha = 0.72$) in the Chinese sample. The subscale for interdependent self-construal includes another five items, such as "[m]y relationships with my friends and family are more important than my personal accomplishments" and "I try to meet demands of my group, even if it means controlling my own desires." The average scale score was 4.99 ($SD = 1.00$, Cronbach's $\alpha = 0.78$) in the American sample and 5.40 ($SD = 0.79$, Cronbach's $\alpha = 0.68$) in the Chinese sample. See Supplementary Table S3 for all scale items.

3.2.3 Health locus of control

A modified scale based on Norman et al. (30) was used to measure the three dimensions of the health locus of control on a 7-point scale (*1 = strongly disagree; 7 = strongly agree*). The health locus of control by internal factors was assessed with three items (e.g., "[i]f I fall ill with the virus, I believe I can recover on my own without going to the hospital"). The average scale score was 5.22 ($SD = 0.32$ and Cronbach's $\alpha = 0.73$) in the American sample and 3.73 ($SD = 1.00$ and Cronbach's $\alpha = 0.60$) in the Chinese sample. The health locus of control by powerful others was measured with three items (e.g., "[i]f I fall ill with the virus, I believe the health care system will help me recover"). The average scale score was 4.92 ($SD = 1.12$ and Cronbach's $\alpha = 0.78$) in the American sample and 5.73 ($SD = 0.89$ and Cronbach's $\alpha = 0.66$) in the Chinese sample. The health locus of control by chance was measured by four items, for example, "[i]t seems as if my health mostly depends on sheer coincidence." The average scale score was 3.89 ($SD = 1.42$ and Cronbach's $\alpha = 0.82$) in the American sample and 2.39 ($SD = 0.99$ and Cronbach's $\alpha = 0.68$) in the Chinese sample. See Supplementary Table S3 for all scale items.

3.3 Data analysis

We utilized Hayes (31) PROCESS to assess national differences in the seven preventive behaviors, along with the mediating effects of the two types of self-construal and three types of health locus of control, which are included as five parallel mediators. To examine these national differences in more detail, we tested all hypotheses except for H2(a-b) separately for each of the seven behaviors, with the p-values adjusted for seven comparisons using Bonferroni's method. Participants' sex, age, marital status, education level, income level, living condition, and employment status were included as covariates to control for potential confounding effects due to associations between demographics and preventive behaviors against COVID-19, which was found in previous research [e.g., (32)]. H2(a-b) involves within-subject comparisons and was tested using paired sample t-tests. Descriptive statistics of the key variables are included in Table 1 (see Supplementary Tables S1, S2 for summaries of the demographics of the two samples). The models and standardized estimates for all hypotheses, except for H2(a-b), are illustrated in Figure 1, along with bootstrapped 99.286% confidence intervals (CIs) (i.e., the

TABLE 1 Descriptive statistics of the key variables.

	Americans (N = 888)		Chinese (N = 844)	
	Mean	SD	Mean	SD
Self-focused preventive behavior				
Washing hands	4.34	0.90	4.11	0.84
Cleaning and disinfecting frequently touched surfaces	4.01	1.06	3.56	1.15
Other-focused preventive behavior				
Covering nose and mouth when sneezing and coughing	4.38	0.91	4.37	0.81
Keeping social distance	4.33	0.87	4.51	0.68
Staying at home	4.18	0.85	4.39	0.69
Avoiding public transportation	4.51	0.85	4.42	0.88
Wearing a face mask	3.38	1.49	4.88	0.41
Self-construal				
Interdependent	4.99	1.00	5.40	0.79
Independent	5.44	0.93	5.28	0.91
Health locus of control				
Internal	5.22	1.04	3.73	1.00
Powerful others	4.92	1.12	5.73	0.89
Chance	3.89	1.42	2.39	0.99

Bonferroni-adjusted 95% CIs for seven comparisons, with 5,000 re-samples) for the indirect effects. The datasets, computer codes for the analyses, and all outputs can be found at https://osf.io/qae9k/?view_only=8cbbcb47c3a4441e8f366f1bad204ee3.

4 Results

H1(a) predicted that Chinese participants would engage less in self-focused preventive behaviors but (b) more in other-involved preventive behaviors than American participants. Supporting H1(a), regression analyses revealed that, compared to Americans, Chinese participants reported less engagement in the two self-focused behaviors, namely, washing hands with $b = -0.17$, $t_{(1723)} = -2.81$, and $p_{adj} = 0.04$ and cleaning and disinfecting frequently touched surfaces with $b = -0.35$, $t_{(1724)} = -4.74$, and $p_{adj} < 0.001$. Regarding H1(b), Chinese participants reported more engagement in three out of the five other-oriented behaviors, namely, wearing face masks with $b = 1.36$, $t_{(1724)} = 18.53$, and $p_{adj} < 0.001$; keeping social distance with $b = 0.31$, $t_{(1724)} = 5.95$, and $p_{adj} < 0.001$; and staying home with $b = 0.29$, $t_{(1724)} = 5.55$, and $p_{adj} < 0.001$, compared to Americans. The national differences in covering nose and mouth when sneezing and coughing ($p_{adj} = 0.98$) and avoiding public transportation ($p_{adj} = 0.99$) were not statistically significant. Therefore, H1(a) was supported while H1(b) was partially supported.

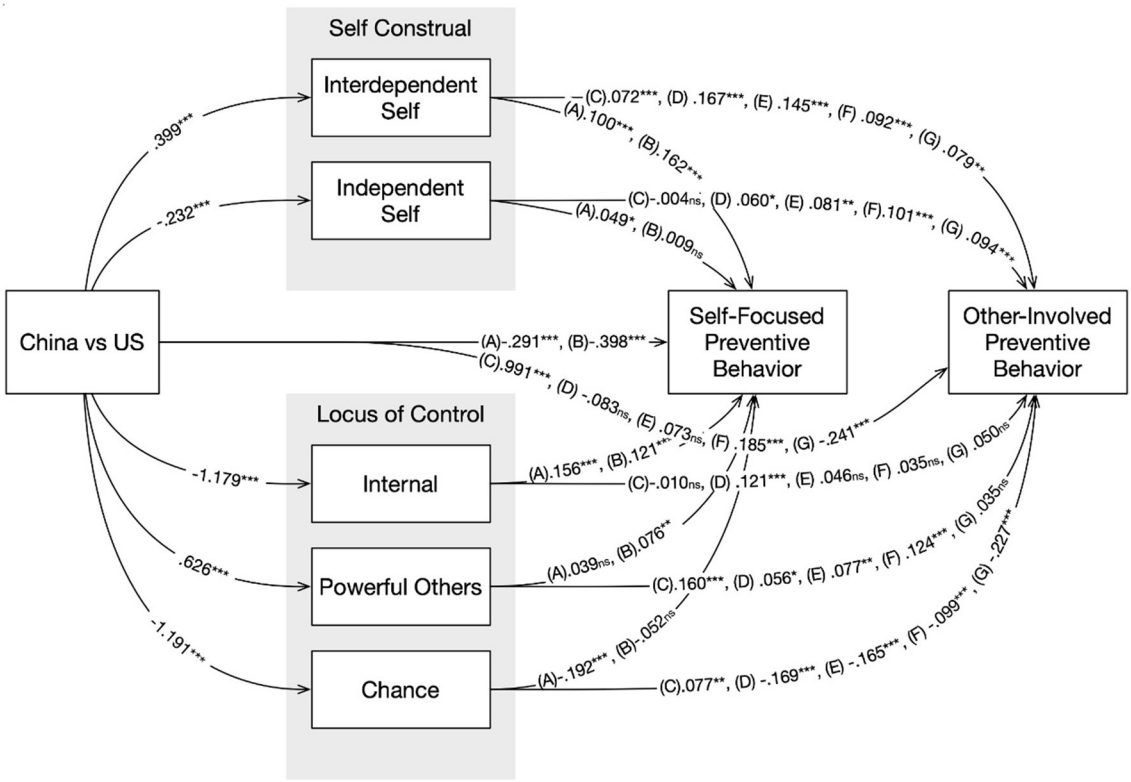
H2(a) predicted that American participants would engage more in self-focused rather than other-involved preventive behaviors, and H2(b) predicted that Chinese participants would engage more in other-involved than self-focused preventive behaviors. Paired-sample t-tests revealed that American participants did not differ in terms of their engagement in self-focused preventive behaviors ($M = 4.18$ and $SD = 0.84$) and other-involved preventive behaviors ($M = 4.15$ and $SD = 0.66$), $t_{(887)} = 0.92$ and $p = 0.36$. However, Chinese participants engaged more in other-involved preventive behaviors ($M = 4.51$ and $SD = 0.39$) than self-focused preventive behaviors ($M = 3.84$ and $SD = 0.87$), $t_{(843)} = 24.61$ and $p < 0.001$. Thus, H2(a) was not supported, but H2(b) was.

H3(a) and H3(b) postulated that interdependent self-construal should encourage both self-focused and other-involved preventive behaviors. Regression analyses showed that interdependent self-construal was positively associated with washing hands with $b = 0.09$, $t_{(1720)} = 3.79$, and $p_{adj} = 0.01$ and cleaning and disinfecting frequently touched surfaces with $b = 0.18$, $t_{(1720)} = 5.86$, and $p_{adj} < 0.001$, thereby supporting H3(a). Similarly, interdependent self-construal was positively associated with wearing face masks with $b = 0.19$, $t_{(1720)} = 6.13$, and $p_{adj} < 0.001$; covering nose and mouth when sneezing and coughing with $b = 0.15$, $t_{(1720)} = 6.66$, and $p_{adj} < 0.001$; keeping social distance with $b = 0.10$, $t_{(1720)} = 4.78$, and $p_{adj} < 0.001$; staying home with $b = 0.08$, $t_{(1720)} = 3.94$, and $p_{adj} < 0.001$; and avoiding public transportation with $b = 0.06$, $t_{(1720)} = 2.68$, and $p_{adj} = 0.049$, thereby supporting H3(b).

H4(a) and H4(b) postulated that independent self-construal will encourage self-focused preventive behaviors but discourage other-involved preventive behaviors. Regression analyses suggested that independent self-construal might not be associated with washing hands ($p_{adj} = 0.30$) or cleaning and disinfecting frequently touched surfaces ($p_{adj} = 0.99$), thus not supporting H3(a). In addition, contrary to H4(b), independent self-construal positively predicted three out of the five other-involved preventive behaviors, namely, keeping social distance with $b = 0.07$, $t_{(1720)} = 3.52$, and $p_{adj} = 0.003$; staying home with $b = 0.09$, $t_{(1720)} = 4.33$, and $p_{adj} < 0.001$; and avoiding public transportation with $b = 0.10$, $t_{(1720)} = 4.14$, and $p_{adj} < 0.001$. Independent self-construal was not associated with wearing face masks ($p_{adj} = 0.99$) or covering nose and mouth were coughing or sneezing ($p_{adj} = 0.06$). Therefore, H4 was not supported, and the reversed finding is discussed later in the article.

H5 was regarding the national differences in the health locus of control. The results showed that, compared to American participants, Chinese participants reported a lower level of health locus of control by internal factors, $b = -1.51$, $t_{(1724)} = -22.25$, and $p_{adj} < 0.001$; a higher level of health locus of control by powerful others, $b = 0.68$, $t_{(1724)} = 10.09$, and $p_{adj} < 0.001$; and a lower level of health locus of control by chance, $b = -1.86$, $t_{(1724)} = -23.33$, and $p_{adj} < 0.001$. Therefore, H5 was supported.

H6(a) and H6(b) predicted that the health locus of control by powerful others was positively associated with both self-focused and other-involved preventive behaviors. The results showed that the health locus of control by powerful others was positively related to cleaning and disinfecting frequently touched surfaces with $b = 0.06$, $t_{(1720)} = 2.15$, and $p_{adj} = 0.03$, but not necessarily washing



Partially Standardized Indirect Effects and 99.286% Confidence Intervals (Bonferroni-Adjusted for 95% with 7 Comparisons)

	Interdependent Self	Independent Self	Internal-HLC	Powerful Others-HLC	Chance-HLC
Self-focused					
(A) Washing hands	**.040 [.008, .080]**	-.011 [-.035, .006]	**-.184 [-.296, -.078]**	.025 [-.023, .081]	**.229 [.134, .329]**
(B) Disinfecting surfaces	**.065 [.029, .112]**	-.002 [-.023, .017]	**-.143 [-.247, -.043]**	**.048 [.0004, .099]**	.062 [-.029, .154]
Other-involved					
(C) Wearing face masks	**.029 [.002, .063]**	.001 [-.013, .018]	.011 [-.074, .102]	**.100 [.052, .157]**	**-.092 [-.179, -.007]**
(D) Covering nose & face	**.067 [.028, .116]**	-.014 [-.039, .002]	**-.143, [-.250, -.044]**	.035 [-.011, .084]	**.201 [.106, .299]**
(E) Social distancing	**.046 [.015, .086]**	**-.019 [-.045, -.001]**	-.054 [-.153, .044]	.048 [-.002, .107]	**.196 [.108, .296]**
(F) Staying at home	**.037 [.009, .074]**	**-.023 [-.056, -.004]**	-.042 [-.152, .065]	**.078 [.032, .132]**	**.117 [.023, .217]**
(G) Avoiding public transportation	**.031 [.005, .067]**	**-.022 [-.049, -.003]**	-.059 [-.166, .039]	.022 [-.021, .067]	**.270 [.181, .366]**

FIGURE 1
Path diagram and standardized coefficients. Coefficients for the seven preventive behaviors were listed on each path, following the order in the in-plot table. Significant indirect effects were bolded in the in-plot table. The following demographics are controlled: sex, age, education level, household income, marital status, and employment status. All significant tests were based on Bonferroni-adjusted p-values for seven comparisons. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, and ns, non-significant.

hands ($p_{adj} = 0.99$), thus partially supporting H6(a). Participants' health locus of control by powerful others was positively associated with wearing face masks with $b = 0.28$, $t_{(1720)} = 10.02$, and $p_{adj} < 0.001$; keeping social distance with $b = 0.06$, $t_{(1720)} = 3.15$, and $p_{adj} = 0.01$; and staying home with $b = 0.09$, $t_{(1720)} = 5.07$, and $p_{adj} < 0.001$ but not necessarily covering nose and mouth when sneezing and coughing ($p_{adj} = 0.33$) or avoiding public transportation ($p_{adj} = 0.99$), partially supporting H6(b).

H7(a) and H7(b) proposed that the health locus of control by chance was negatively associated with both self-focused and other-involved preventive behaviors. Regression analyses revealed that health locus of control by chance was negatively related to engagement in washing hands with $b = -0.10$, $t_{(1720)} = -6.43$, and $p_{adj} < 0.001$ but not necessarily cleaning and disinfecting frequently touched surfaces ($p_{adj} = 0.99$), partially supporting H7(a). Similarly, the health locus of control by chance was negatively associated with wearing face masks with $b = -0.06$, $t_{(1720)} = -2.75$, and $p_{adj} = 0.04$; covering nose and mouth when sneezing and coughing with $b = -0.10$, $t_{(1720)} = -6.49$, and $p_{adj} < 0.001$; keeping social distance with $b = -0.11$, $t_{(1720)} = -7.52$, and $p_{adj} < 0.001$; staying home with $b = -0.08$, $t_{(1720)} = -5.37$, and $p_{adj} < 0.001$; and avoiding public transportation with $b = -0.13$, $t_{(1720)} = -8.35$, and $p_{adj} < 0.001$. Therefore, H7(b) was supported.

Finally, H8(a) and H8(b) predicted that health locus of control by internal factors would be positively associated with self-focused preventive behaviors but negatively associated with other-involved preventive behaviors. Supporting H8(a), regression analyses showed that health locus of control by internal factors was positively associated with washing hands with $b = 0.12$, $t_{(1720)} = 6.50$, and $p_{adj} < 0.001$ and cleaning and disinfecting frequently touched surfaces with $b = 0.15$, $t_{(1720)} = 6.13$, and $p_{adj} < 0.001$. In terms of other-involved preventive behaviors, health locus of control by internal factors was negatively related to wearing facemasks with $b = -0.15$, $t_{(1720)} = -5.68$, and $p_{adj} < 0.001$ but not

necessarily keeping social distance ($p_{adj} = 0.99$), staying home ($p_{adj} = 0.99$), or avoiding public transportation ($p_{adj} = 0.07$). Contrary to the prediction, participants' health locus of control by internal factors was positively associated with engagement in covering nose and mouth when sneezing and coughing with $b = 0.08$, $t_{(1720)} = 4.22$, and $p_{adj} < 0.001$. Therefore, H8(b) was supported for only one out of the five other-involved preventive behaviors.

5 Discussion

This study identified significant national differences between Americans and Chinese people's engagement in seven preventive behaviors that are commonly recommended by public health authorities to battle a public health crisis. To theorize these national differences, we proposed two conceptual types of preventive behaviors, namely, self-focused and other-involved behaviors. The findings suggest that Americans engaged more in self-focused preventive behaviors (i.e., washing hands and disinfecting surfaces) than Chinese, whereas Chinese engaged more in the majority of the other-focused preventive behaviors (i.e., wearing face masks, keeping social distance, and staying home) than Americans. Additionally, Chinese participants reported greater engagement in other-involved preventive behaviors than self-focused behaviors, although we only observed non-significant differences between the two types of behaviors reported by American participants. Moreover, we found that these national differences can be explained by two psychological traits, namely, self-construal and health locus of control.

The distinction between self-focused and other-involved preventive behaviors, along with the identification of self-construal and the health locus of control as two individual-level mechanisms, contributed to the understanding of preventive behaviors for public health crises. The two-fold distinction of health preventive behaviors highlights the communal nature of many public health crises: while it is reasonable to emphasize the importance of self-focused preventive behaviors in managing many personal health issues, communal risks imposed by large-scale health crises require not only self-protection but also collective actions involving others' efforts (4). Previous research on health promotion has centered on self-focused behaviors such as smoking cessation, weight loss, and depression treatment [for a meta-analysis, see (33)]. Studies examining public health crises, such as Middle East respiratory syndrome or coronavirus, have primarily focused on how exposure and processing of health information contributed to risk perceptions and subsequent preventive behaviors [e.g., Choi et al. (34); Nazione et al. (35)]. However, these studies have often overlooked the conceptual or empirical differentiation of various preventive behaviors. Acknowledging the communal nature of some public health issues helps to connect the health communication research that focuses on individual behaviors with other social scientific research that highlights the interdependence among individuals, such as risk management/communication, group and intergroup processes, and social movements.

The two individual traits, namely, self-construal and health locus of control, help us further understand the diverse responses to public health crises. They serve as the individual-level mechanisms that partially explain the national differences in self-focused and other-involved preventive behaviors. While some established health prevention models (e.g., the Health Belief Model, (36); the Extended Parallel Process Model, (37) often do not consider culture-induced individual differences (38), our model and findings highlight the importance of such differences. The observed national differences between Americans and Chinese in the health locus of control not only exemplify the distinctive national cultures of the two societies but also mirror variances in their institutional healthcare frameworks (e.g., health institutions are predominantly state-owned in China, while privatized in the United States). These results highlight the importance of designing health campaigns and interventions tailored to the national culture as well as societal and institutional frameworks.

However, our data still left a few hypotheses unconfirmed and even reversed, demanding further explanations and investigations. First, it was surprising to find a positive association between independent self-construal and engagement in several other-involved preventive behaviors. One possible explanation is that, although other-involved preventive behaviors imply a greater awareness of interdependence compared to self-focused behaviors, these behaviors are not intrinsically altruistic and are still tied to self-interest. Therefore, it is possible that independent self-construal would also motivate other-involved preventive behaviors—especially if the individuals were aware of the self-interest in other-involved preventive behaviors. In other words, the awareness of self- vs. other-interest implied in preventive behaviors may be an important boundary condition of this part of our model and thus deserves further investigation.

Second, although the between-nation differences in the two types of preventive behaviors largely confirmed our hypotheses (H1a and b), the within-nation differences were less clear. While Chinese participants indeed reported greater engagement in other-involved behaviors compared to self-focused preventive behaviors (supporting H2b), the two types of preventive behaviors did not differ among American participants (rejecting H2a). One possible explanation could be that Americans may not differentiate between self-focused and other-involved preventive behaviors as much as their Chinese counterparts. Considering that both types of preventive behaviors were recommended and even reinforced by governments and health authorities, Americans might either accept these recommended preventive behaviors as a whole or completely reject them. By analyzing 12-week Twitter posts on mask-wearing, Rains et al. (33) found that public anger was not centered around the mask mandates as an obstacle to personal freedom; instead, mask-wearing was deemed as protection from harm. Moreover, the COVID-19 pandemic has been largely politicized and Americans have polarized opinions and attitudes regarding the perceived risk, trust in politicians to handle the pandemic, and trust in health authorities such as the World Health Organization (39) (40). Future studies should continue to examine the within-national variations in responses to the two types of preventive behaviors and how political ideology and partisanship account for these variations.

Finally, the proposed negative impact of health locus of control by internal factors on other-involved preventive behaviors was not observed. It is possible that, on the one hand, individuals with a higher locus of control by internal factors may perceive other-involved preventive behaviors to be less controllable by themselves and, thus, are discouraged from engaging in these behaviors. On

the other hand, individuals may recognize the benefits of other-involved preventive behaviors even without others' cooperation and attempt to still engage. Future research should examine whether the two competing mechanisms could explain the absence of an association between the health locus of control by internal factors and engagement in other-involved preventive behaviors.

5.1 Practical implications

Our findings offer implications for designing communication interventions to maximize the impacts of health campaigns aimed at preventing a public health crisis. Instead of attempting to identify a one-size-fits-all solution, our study suggests that recovery from a public health crisis requires tailored interventions. Although national culture and its dimensions, such as individualism-collectivism, power distance, and indulgence, are presumably stable and universal within societies, the related individual traits are not. Traits including self-construal and health locus of control are situation-dependent and can be intervened through persuasion and other forms of communication. Policymakers and communication practitioners should take into account the underlying psychological mechanisms in designing intervention messages (41). For instance, highlighting interdependence in coping with communal risks in a public health crisis may evoke individuals' interdependent self-construal and motivate them to perform other-involved preventive behaviors. Similarly, messages that emphasize the roles of self and public health authorities in crisis containment may instill confidence in people to adopt both self-focused and other-involved preventive behaviors. Embedding such cultural beliefs in health campaigns and health message designs will help promote individuals' health perceptions and behaviors.

5.2 Limitations

This study has several limitations. First, although we have collected survey data from both the United States and China, the data were cross-sectional, limiting our ability to test for causal relationships. Second, this study used online survey tools to recruit participants. Considering the digital divide and possible self-selection bias, the participants recruited from the online survey panel may not represent the entire population of each country. Third, while the study emphasized individual-level psychological mechanisms for preventive behaviors between the United States and China, cultural dimensions were incorporated as umbrella concepts without an empirical assessment of their relationships with individual behaviors. The dynamic and complex nature of culture may not be fully captured by the variables being examined in the current study. Fourth, the scale to measure the health locus of control exhibited relatively lower reliability within the Chinese sample. Since the health locus of control has rarely been measured with Chinese participants and no valid Chinese version of the measure has been developed, the scale utilized in this study was an appropriate choice. Finally, the dichotomization of self-focused and other-involved behaviors may simplify the complex interplay between individual and communal health practices, as certain preventive behaviors may be related to both types.

5.3 Future directions

We propose several directions to continue this line of research. First, future studies should adopt longitudinal designs to establish causal relationships and monitor changes in individuals' perceptions, social norms, and behaviors in response to public health crises. In relation to the design, future studies should use more comprehensive and sophisticated sampling techniques to acquire national representative samples to compare the national differences in response to public health crises.

Future studies should further explore additional cultural factors manifested at various levels, including individual, community, organizational, and societal levels. Factors such as risk perceptions, social integration, political views, and governmental reinforcements of preventive behaviors potentially contribute to cultural differences in responses to a public health crisis. For instance, while lockdowns were implemented in both China and the United States during the data collection period, the level of reinforcement strictness varied between the two countries, resulting in potential differences in the adoption of preventive behaviors.

Finally, future studies should continue to extend and apply the self-focused vs. other-involved dichotomy of preventive behaviors. Although the current study only provides preliminary findings regarding this dichotomized construct, future studies could explore its applicability to other types of preventive behaviors aimed at minimizing individual and communal risks and assess the boundary of such categorizations.

6 Conclusion

By using two large-scale cross-sectional surveys conducted in the United States and China, this study found that, when facing public health crises, Americans engaged more in self-focused preventive behaviors, while Chinese engaged more in other-involved preventive behaviors. Within each country, Americans engaged more in self-focused than other-involved preventive behaviors, while Chinese engaged more in other-involved than self-focused preventive behaviors. The national differences in people's engagement in preventive behaviors between the United States and China can be partially explained by individuals' independent and interdependent self-construals, as well as their health locus of control. The culture-sensitive approach exemplified a meaningful and fruitful way to advance our understanding of public health preventive behaviors in the increasingly globalized world.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the College of Journalism and Communication, Renmin University of China. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

WP: Writing – original draft, Writing – review & editing. WL: Writing – original draft, Writing – review & editing. BF: Writing – original draft, Writing – review & editing. SL: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Retrospective study on the emotional status of healthcare workers in a COVID-19 field hospital in Oman

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Overview: To combat the overwhelming demand for medical services and care during the COVID-19 Pandemic, the Sultanate of Oman launched the COVID-19 Field Hospital in 2020, designed to respond and alleviate the burden on the medical infrastructure. Several studies globally and from the Middle East suggested that frontline healthcare workers (HCW) were at risk of developing markers of psychological distress. It was further understood through research findings that HCW were resilient during times of crisis. However, there is a dearth in studies evaluating the emotional status of frontline HCW posted in the COVID-19 field hospitals in Gulf Countries, including Oman. This study attempts to shed light on the emotional status of HCW that were on the frontlines in the field hospital in the Sultanate of Oman.

Aim: This study aims to quantify and evaluate the emotional status of HCW in the frontline field hospital by screening for symptoms of depression, anxiety, and sleep quality.

Method: The data was collected by a local private mental healthcare facility as part of digital feedback to design and implement supportive strategies. Data was collected between September 2021 and October 2021 from 121 HCW in the COVID-19 Field hospital in Oman via 'WhatsApp'.

Results: Chi square and binary logistic regression tests were administered to evaluate the data. The participants comprised of 63.6% females and 79.3% were between 30 and 39 years of age. Majority of the participants (65.2%) described themselves as 'financially unstable' and possess an average of 7.5 years of work experience. Of the participants 73.6% of the HCW were based solely in the field hospital for 6–9 months at the time of the survey. Majority of the participants denied the presence of emotional distress expressed through depression (92.6%), anxiety (92.6%) and poor quality of sleep (59.5%).

Conclusion: The findings of the present study reflect the HCW ability to cope during challenging situations likely owing to a variety of environmental, social and personal protective factors. The findings of this study can translate into further research on identifying and addressing stressors and targeting the enhancement of protective factors to safeguard the well-being of HCW.

KEYWORDS
healthcare worker (HCW), Oman, COVID-19, field hospital, psychological status

1 Introduction

The World Health Organization (WHO) declared the COVID-19 outbreak as a public health emergency and a global pandemic in March 2020. Despite COVID-19 no longer being classified as a 'Global Health Emergency' by the WHO since May 2023 (1), literature has emerged highlighting the need for preservation of the well-being of healthcare workers (HCW) during crisis (2). As per the consideration of the WHO, HCWs are a classification of "all people primarily engaged in actions with the primary intent of enhancing health." This includes all individuals involved in activities aimed at improving health (3). Past literature on pandemics has highlighted the negative emotional status of healthcare workers (HCWs), stemming from increased workload, uncertain hospital procedures and policies, and perceived risk of infection and stigma (4).

Emotional Status' is regarded as the feelings experienced by an individual or a collective group in relation to a particular situation, which may encompass psychological distress (5). Since the onset of COVID-19, findings have emerged recognizing and highlighting the prevalence of psychological distress among HCW during the pandemic (6–8). Similarly, numerous cross-sectional studies reported high rates of depressive and anxiety symptoms, as well as sleep disturbances and burnout among HCWs (9–12). The shortage of HCWs, coupled with hospitals operating beyond their capacity, has contributed to burnout and exhaustion among HCWs (13, 14). Due to hospitals being overwhelmed by the sheer volume of patients and the consequent impact on the well-being of HCWs, field hospitals have emerged as a recognized and strategic tool used by countries to alleviate the burden on established health facilities and mitigate the spread of the virus in the community (15, 16).

Field hospitals have a long history in military contexts, where they serve as temporary, mobile medical facilities designed to triage, stabilize, resuscitate, and provide acute care to wounded soldiers near battlefields (17). The Oman News Agency (18) reported that on October 10, 2020, the Ministry of Health (MOH) in Oman launched a COVID-19 field hospital at the location of the former Muscat International Airport, which held a capacity of over 300 beds and offered full-time management of mild, moderate, and severe cases of COVID-19. The hospital was equipped with a pharmacy, laboratory, and radiology department with over 40 doctors, 200 nursing staff, and a range of other healthcare professionals such as lab technicians, pharmacy assistants, physiotherapists, and radiologists to support its operations (19). These facilities have played a critical role in alleviating the burden on medical infrastructure during the surge of the pandemic by offering focused and essential care to COVID-19 patients.

Badahdah et al. (20) reported findings from Oman indicating that HCWs who were in direct contact with COVID-19 patients experienced a higher level of psychological distress and disturbed sleep, compared to their counterparts who were not in direct contact with COVID-19 patients (21). In addition, socio-demographic factors such as gender, age, marital status, socio-economic background, and social support were found to be significant predictors of the psychological distress experienced by frontline HCWs in Oman (7). More specifically, being female, financially unstable, and receiving treatment for mental illness were identified as independent predictors of psychological distress. While many studies have highlighted predictors of psychological distress and the negative impact of the pandemic on HCWs mental wellbeing, others have shown that protective factors, such as resilience, self-efficacy, and healthy coping skills, can improve mental health outcomes (22–24). In fact, a number of studies have reported that HCWs possessed greater resilience despite the adversities associated with the pandemic, including lack of adequate social connection, shift work, lengthy working hours, inadequate hospital supplies, and unpredictability (25). Factors identified as coping mechanisms by HCWs that enhanced their ability to rebound included social support (24, 26), religious activity (27, 28), distraction techniques (27, 29), and adherence to infection control guidelines (27, 30).

Numerous studies from the Arab Peninsula evidenced the negative impact of COVID-19 on HCW's mental health, however, there is a paucity of data emerging from HCW that operated solely in COVID-19 field Hospitals. As such, the purpose of this study is to address this gap by investigating the mental health status, as indicated by psychological variables and quality of sleep, of HCWs at a COVID-19 field hospital in Oman. The findings of this study may have important implications for policy makers and mental health practitioners in developing effective prevention strategies and policies to reduce the risk of mental health problems among medical responders to the COVID-19 pandemic in Oman, as well as to enhance preparedness for future pandemics. Thus, the present study aims to assess the emotional wellbeing of HCWs at an Omani field hospital by screening them against scales that quantify depression, anxiety, and quality of sleep.

2 Methodology

2.1 Participants

All 280 HCWs that were operating in the COVID-19 Field Hospital in Oman were invited to participate in the study via social media platforms such as Whatsapp and email services in September 2021. HCWs who were either medical (physicians and nurses) or nonmedical personnel (allied health professionals, pharmacists, and technicians), above 18 years of age, and English or Arabic speakers were eligible to participate. Participants in this cross-sectional study comprised of both Omani and non-Omani HCWs who offered their services at the field hospital any time between October 2020 and September 2021. A sample of 121 HCWs from the COVID-19 field hospital at the Sultanate of Oman gave their consent to participate in this study. Upon obtaining informed consent, all participants were required to complete a 15-min online survey which was shared in both Arabic and English via WhatsApp and email services. The survey comprised of sociodemographic information and questionnaires such

as the Patient Health Questionnaire (PHQ-9), the Generalized Anxiety Disorder-7 (GAD-7) and the Pittsburg Sleep Quality Index (PSQI). The screening measures were shared with the standardized instructions to recall experiences and respond to the items in the questionnaires as per the original design. Thus instructions were included for the participants to respond to the PHQ-9 and GAD-7 based on their experiences recalled within the previous 2 weeks, and a recall of 4 weeks for the PSQI.

2.2 Measures

2.2.1 Sociodemographic information

A form was given to each participant requesting information such as their age, gender, marital status, nationality, number of dependents, years of medical work experience, time of service at the field hospital, and economic status.

2.2.2 Patient health questionnaire-9

The PHQ-9 is a freely available screening measure comprising of 9 items that is used in the tentative diagnosis of depression and its severity. A cut-off score of 10 on the PHQ-9 was identified as offering a sensitivity of 80.6% and specificity of 94% among Omani HCW (31). For the utilization in this study, a cut-off score of 10 determined the presence of depressive symptoms among HCWs in the sample.

2.2.3 Generalized anxiety disorder-7

The GAD-7 is a freely available, self-report questionnaire comprising of 7 items that requires participants to reflect on their experience of anxiety over the last 2 weeks. The validated questionnaire in Arabic recommends a cut-off score of 10 for more precise sensitivity and specificity of screening for symptomology of anxiety among respondents (32).

2.2.4 Pittsburg sleep quality index

The PSQI comprises of 19-items reporting the quality of sleep experienced over the last month by reviewing various aspects of sleep quality and disturbance. Poor sleep is indicated by any score ranging from 5 to 21on the PSQI with higher scores suggesting a poorer quality of sleep. However in order to ensure the internal consistency and construct validity of the Arabic translation of the PSQI, the cut-off score to mark poor quality of sleep in this study was 3 (33).

2.3 Procedure

The study followed a standard procedure for data collection. Owing to social and physical restrictions during the COVID-19 pandemic, HCW who were on the popularly used text-based Smartphone application 'WhatsApp' were contacted via the app and given written and verbal information about the study. Participants were requested to complete an online survey using a link on 'Google Forms'. The form comprised of the information sheet which included information relevant to the study stating the purpose of the study and what their participation will involve. The form also included the following questionnaires: the sociodemographic form, PHQ-9, GAD-7, and PSQI. A debriefing form that restated the study's purpose and thanked participants for their participation, along with contact details of the researchers was also included in the form. Participants were able to complete the survey at their own pace and at a time that was convenient for them. Once participants completed the survey, they submitted their responses by clicking the "Submit" icon at the bottom of the screen. The responses were forwarded to a secure email that was set up specifically for the purpose of storing the online responses privately. The data was collected and summarized in SPSS V.26 from 121 participants who met the inclusion criteria for the purpose of this study. All completed response sheets were anonymized to maintain confidentiality and compiled into a private dataset that was stored on a password-protected computer. This procedure ensured that the data was kept confidential and secure.

2.4 Statistical analysis

The frequency and percentages (%) were calculated for each categorical variable. Continuous variables were described using mean ± standard deviation. The Chi square test was used to test the association between demographic variables and anxiety, depression, and quality of sleep. Binary logistic regression tests were used to test the effect of quality of sleep on anxiety and depression. In all tests, significant levels of 0.05 ($p = 0.05$) were used. For the analysis, we used the Statistical Package for Social Science (SPSS v.26).

2.5 Ethics statement

The present research received ethical approval from the Health Studies and Research Approval Committee (HSRAC), Ministry of Health Oman, proposal ID: MoH/CSR/22/26365. All participants provided informed written consent prior to participating in the study. They were required to read through an information sheet summarizing the aims of the study and how their data will be stored. They were informed of their right to withdraw from the study at any point and that they have the choice to delete their responses even after completing the survey. They were also made aware that all their information would remain anonymous and may not be tracked back to them in any way. Finally, participants were informed that there were no expected risks or harm associated with participating in the study. However, to mitigate any risk to their mental well-being as a result of participating in the study, the researchers included mental health resources and contact emails of the authors in the information sheet and debrief form.

3 Results

A total of 121 healthcare workers (HCWs) from the COVID-19 Field hospital in Oman participated in this study, offering insight into the sociodemographic profiles and various characteristics within a field hospital setting. The distribution of gender among participants skewed toward females, who comprised 63.6% ($n = 77$) of the sample, compared to 36.4% males ($n = 44$). This gender disparity highlights the prominent role of female HCWs in the healthcare setting under study and may reflect broader trends within the healthcare profession or specific recruitment patterns of this study.

Age distribution among participants indicates a significant concentration in the 30–39 years age bracket, with 79.4% ($n=96$) of the sample falling within this range. This suggests that the workforce is relatively young, which could have implications for the energy levels, technological adaptability, and possibly the stress resilience of the workforce. The relatively smaller proportions of younger (13.2%, $n=16$) and older (7.4%, $n=9$) workers suggest less diversity in age, which might influence the dynamics of teamwork and peer support within the hospital.

Regarding marital status, a vast majority of participants were married (82.7%, $n=100$), with single individuals accounting for 12.4% ($n=15$), and very few divorced (0.8%, $n=1$) or engaged (4.1%, $n=5$). The high prevalence of married individuals could indicate a need for work-life balance considerations and support structures for family obligations among the workforce.

Nationality data reveal that 90.9% ($n=110$) of the participants were non-Omani, highlighting a workforce predominantly composed of expatriates. This has significant implications for cultural diversity and possibly the adaptation challenges and social support systems available to the HCWs in the field hospital.

The number of dependents shows a roughly even split between those with fewer than 3 dependents (47.0%, $n=47$) and those with 3 to 5 dependents (48.0%, $n=48$), with a small fraction having more than 5 dependents (5.0%, $n=5$). This distribution suggests a significant portion of the workforce faces considerable family responsibilities outside of their professional roles.

Work experience, measured as an average of 7.22 years with a standard deviation of 4.98, indicates a moderately experienced workforce. The range in years of experience suggests diversity in the level of expertise and possibly differences in approaches to patient care and adaptability to the field hospital's demanding environment.

The time spent in the field hospital shows that a large majority of participants (73.6%, $n=90$) have been working for 6–9 months, with a notable group (24.0%, $n=29$) exceeding 10 months. This indicates that most of the workforce has had a substantial duration of direct exposure to the specific challenges of the field hospital setting.

Economically, 65.2% ($n=79$) of participants reported unstable financial status, with only 32.3% ($n=39$) feeling comfortable financially. This suggests that economic concerns are prevalent among the workforce, which could have implications for their mental health and overall well-being (Table 1).

The prevalence of depression and anxiety was reported at 7.4% for both conditions ($n=9$ for each), indicating that these mental health challenges, while not dominant, are present among the HCWs. The quality of sleep problem was more pronounced, with 40.5% ($n=49$) of the participants reporting issues, highlighting a significant area of concern for worker health and performance.

In summary, the sociodemographic and characteristic profile of the HCWs in this study provides critical insights into the workforce's composition and potential needs. The predominance of a young, predominantly female, and married workforce, with a significant portion experiencing financial instability and sleep quality issues, points to several areas for policy intervention, including mental health support, financial counseling, and initiatives to improve work-life balance and well-being.

Table 2 examines the prevalence of GAD among healthcare workers (HCWs) in relation to demographic and work-related variables. Notably, a significant difference in anxiety levels is observed based on marital status and nationality, with engaged HCWs experiencing higher anxiety rates (100%) and Omani nationals showing a markedly higher prevalence of anxiety (45.5%) compared to their non-Omani counterparts (3.6%). These findings suggest that social and cultural factors may significantly influence mental health

TABLE 1 Sociodemographic data and other characteristics of the sample.

Category	N (%)
Gender	
Male	44 (36.4%)
Female	77 (63.6%)
Age	
18–29	16 (13.2%)
30–39	96 (79.4%)
40–50	9 (7.4%)
Marital Status	
Single	15 (12.4%)
Married	100 (82.7%)
Divorced	1 (0.8%)
Engaged	5 (4.1%)
Nationality	
Omani	11 (9.1%)
Non- Omani	110 (90.9%)
Number of Dependents	
< 3 dependents	47 (47.0%)
3–5 dependents	48 (48.0%)
> 5 dependents	5 (5.0%)
Years of work experience	
(Mean ± SD)	7.22 ± 4.98
Time Spent in Field Hospital	
< 2 Months	0 (0.0%)
2–5 Months	2 (1.7%)
6–9 Months	90 (73.6%)
>10 Months	29 (24.0%)
Economic Status	
Comfortable Financially	39 (32.3%)
Financial Status Unstable	79 (65.2%)
Very Comfortable Financially	3 (2.5%)
Depression	
Yes	9 (7.4%)
No	112 (92.6%)
Anxiety	
Yes	9 (7.4%)
No	112 (92.6%)
Quality of sleep Problem	
Yes	49 (40.5%)
No	72 (59.5%)

$N=121$.

TABLE 2 Generalized anxiety disorder based on several variables.

Category	HCW without anxiety N (%)	HCW with anxiety N (%)	*p* value
Gender			
Male	43 (97.7%)	1 (2.3%)	<0.102
Female	69 (89.6%)	8 (10.4%)	
Age			
18–29	13 (81.3%)	3 (18.8%)	
30–39	91 (94.8%)	5 (5.2%)	<0.146
40–50	8 (88.9%)	1 (11.1%)	
Marital Status			
Single	81 (95.3%)	4 (4.7%)	
Married	26 (86.7%)	4 (13.3%)	<0.002*
Divorced	5 (100%)	0 (0%)	
Engaged	0 (0%)	1 (100%)	
Nationality			
Omani	6 (54.5%)	5 (45.5%)	<0.000*
Non- Omani	106 (96.4%)	4 (3.6%)	
Number of Dependents			
< 3 dependents	42 (89.4%)	5 (10.6%)	
3–5 dependents	45 (93.8%)	3 (6.3%)	<0.401
> 5 dependents	3 (75%)	1 (25%)	
Years of work experience			
(Mean ± SD)	7.17 ± 5.01	7.79 ± 4.91	<0.722
Time Spent in Field Hospital			
< 2 Months	1 (50%)	1 (50%)	
2–5 Months	86 (95.6%)	4 (4.4%)	<0.017*
6–9 Months	25 (86.2%)	4 (13.8%)	
>10 Months	1 (50%)	1 (50%)	
Economic Status			
Comfortable Financially	32 (84.2%)	6 (15.8%)	
Financial Status Unstable	76 (97.4%)	2 (2.6%)	<0.009*
Very Comfortable Financially	2 (66.7%)	1 (33.3%)	
Depression			
No	108 (96.4%)	4 (3.6%)	<0.000*
Yes	4 (44.4%)	5 (55.6%)	
Quality of sleep Problem			
No	70 (98.6%)	1 (1.4%)	<0.002*
Yes	40 (83.3%)	8 (16.7%)	

$N = 121$. $p = 0.05$.
*Significant level at 0.05.

outcomes among HCWs. Additionally, economic status and time spent in the field hospital were significantly related to anxiety levels, indicating that financial instability and prolonged exposure to the field hospital environment may exacerbate anxiety among HCWs. The relatively high anxiety rates among those with a "comfortable" financial status (15.8%) compared to the "financially unstable" group (2.6%) underscore the complex relationship between perceived economic well-being and mental health.

Table 3 focuses on the association between depressive symptoms and various sociodemographic factors among HCWs. The analysis reveals a statistically significant relationship between age and depression, with younger HCWs aged 18–29 and those aged 40–50 showing higher rates of depression compared to the 30–39 age group. This suggests that the youngest and oldest segments of the workforce may be more susceptible to depression, possibly due to different stressors and challenges faced at these career stages. Nationality again

TABLE 3 Relationship between depressive symptoms and sociodemographic variables.

Category	HCW without depression N (%)	HCW with depression N (%)	*p* value
Gender			
Male	43 (97.7%)	1 (2.3%)	<0.102
Female	69 (89.6%)	8 (10.4%)	
Age			
18–29	13 (81.3%)	3 (18.8%)	
30–39	92 (95.8%)	4 (4.2%)	<0.026*
40–50	7 (77.8%)	2 (22.2%)	
Marital Status			
Single	81 (95.3%)	4 (4.7%)	
Married	25 (83.3%)	5 (16.7%)	<0.164
Divorced	5 (100%)	0 (0%)	
Engaged	1 (100%)	0 (0%)	
Nationality			
Omani	6 (54.5%)	5 (45.5%)	<0.000*
Non- Omani	106 (96.4%)	4 (3.6%)	
Number of Dependents			
< 3 dependents	43 (91.5%)	4 (8.5%)	
3–5 dependents	45 (93.8%)	3 (6.3%)	<0.778
> 5 dependents	4 (100%)	0 (0%)	
Years of work experience			
(Mean ± SD)	7.06 ± 4.77	9.06 ± 7.01	<0.251
Time Spent in Field Hospital			
< 2 Months	0 (0.0%)	0 (0.0%)	
2–5 Months	1 (50%)	1 (50%)	<0.048*
6–9 Months	85 (94.4%)	5 (5.6%)	
>10 Months	26 (89.6%)	3 (10.4%)	
Economic Status			
Comfortable Financially	33 (86.8%)	5 (13.2%)	
Financial Status Unstable	75 (96.2%)	3 (3.8%)	<0.048*
Very Comfortable Financially	2 (66.7%)	1 (33.3%)	
Anxiety			
No	108 (96.4%)	4 (3.6%)	<0.000*
Yes	4 (44.4%)	5 (55.6%)	
Quality of sleep Problem			
No	70 (98.6%)	1 (1.4%)	<0.002*
Yes	40 (83.3%)	8 (16.7%)	

$N = 121$, $p = 0.05$.
*Significant level at 0.05.

plays a critical role, with Omani HCWs showing a higher prevalence of depressive symptoms (45.5%) than non-Omanis (3.6%), highlighting the potential impact of cultural and societal factors on mental health. The relationship between time spent in the field hospital and depression, particularly among those with shorter and longer durations, suggests that the initial adjustment period and long-term exposure to stressful work environments may contribute to depressive symptoms.

Table 4 examines the impact of sociodemographic factors on the quality of sleep among HCWs. A notable finding is the significant difference in sleep quality based on nationality, with Omani HCWs experiencing more sleep difficulties (81.8%) compared to non-Omanis (36.1%). This might reflect cultural, environmental, or work-related differences affecting sleep. The table also indicates that age and gender may influence sleep quality, with older HCWs and females reporting more sleep problems. The correlation between generalized anxiety

TABLE 4 Relationship between quality of sleep and sociodemographic variables.

Grouping	HCW without sleep difficulties N (%)	HCW with sleep difficulties N (%)	*p* value
Gender			
Male	31 (70.5%)	13 (29.5%)	<0.064
Female	41 (53.3%)	36(46.7%)	
Age			
18–29	11 (68.2%)	5 (33.3%)	
30–39	59 (61.5%)	37 (38.5%)	<0.052
40–50	2 (25%)	6 (75%)	
Marital Status			
Single	52 (61.9%)	32 (38.1%)	
Married	14 (50.0%)	15 (50.0%)	<0.107
Divorced	5 (100%)	0 (0%)	
Engaged	0 (0%)	1 (100%)	
Nationality			
Omani	2 (18.2%)	9 (81.8%)	<0.000*
Non- Omani	70 (63.9%)	40 (36.1%)	
Number of Dependents			
< 3 dependents	30 (63.8%)	17 (36.2%)	
3–5 dependents	26 (55.3%)	21 (44.7%)	<0.286
> 5 dependents	1 (25%)	3 (75%)	
Years of work experience			
(Mean ± SD)	6.79 ± 4.61	7.65 ± 5.33	<0.266
Time Spent in Field Hospital			
< 2 Months	0 (0.0%)	0 (0.0%)	
2–5 Months	1 (50%)	1 (50%)	<0.954
6–9 Months	54 (60.2%)	36 (39.8%)	
>10 Months	17 (58.6%)	12 (41.4%)	
Economic Status			
Comfortable Financially	19 (50.0%)	19 (50.0%)	
Financial Status Unstable	52 (66.7%)	26 (33.7%)	<0.141
Very Comfortable Financially	1 (33.3%)	2 (66.7%)	
Generalized Anxiety Disorder			
No	70 (63.6%)	40 (36.4%)	<0.002*
Yes	1 (11.1%)	8 (88.9%)	
Quality of sleep Problem			
No	70 (63.6%)	40 (36.4%)	<0.002*
Yes	1 (11.1%)	8 (88.9%)	

$N = 121$, $p = 0.05$.
*Significant level at 0.05.

disorder and sleep difficulties is strongly evident, with those suffering from anxiety much more likely to experience sleep problems (88.9% with sleep difficulties), suggesting a close interrelation between anxiety and sleep quality.

The analysis across Tables 2–4 illuminates the intricate web of factors influencing anxiety, depression, and sleep quality among healthcare workers. Marital status, nationality, economic status, and the duration of time spent in a high-stress field hospital environment emerge as significant determinants of mental health and well-being. The higher prevalence of anxiety and depression among certain demographic groups, particularly Omani HCWs, points to the need for targeted mental health interventions. Moreover, the clear association between anxiety and poor sleep quality underscores the importance of addressing mental health issues as part of holistic

TABLE 5 Logistic regression results for predictors of psychological distress.

	B	S.E.	Wald	df	Sig.	Exp(B)	Cox & Snell R Square
GAD	2.110	0.541	15.207	1	0.000	8.246	0.238
Nationality	1.795	1.172	2.345	1	0.126	6.019	
Constant	−0.866	0.234	13.744	1	0.000	0.421	

approaches to improving the overall health and productivity of the healthcare workforce.

The core of our analysis centers on a binary dependent variable—quality of sleep (problematic vs. non-problematic), our study delves into the impacts of sleep quality on psychological distress, namely anxiety, depression and nationality. This specificity, combined with our distribution, situates our study within a framework where traditional Event Per Variable (EPV) considerations are met for our one predictor logistic regression model. According to the widely acknowledged EPV rule, a minimum of 10 events per predictor variable is recommended to ensure stable parameter estimates. Our dataset exceeds this threshold, with more than 24 events for each category per predictor, ostensibly aligning with the basic statistical requirements for logistic regression analysis. This study by Peduzzi et al. (34) is pivotal because it investigates the effect of the number of events per variable (EPV) on the reliability of logistic regression coefficients, concluding that a minimum of 10 events per predictor is needed for reliable estimates. This rule of thumb has been widely adopted in statistical analyses to guide sample size and predictor selection in logistic regression models, thereby underpinning the methodological foundation of our study and reinforcing the adequacy of our sample distribution for the intended analysis (Table 5).

A logistic regression analysis was conducted to explore factors influencing PSQI (likely indicating presence/absence of a condition). The results revealed a strong positive association between General Depression and Anxiety Disorder (GAD) and PSQI. For every one-unit increase in GAD score, the odds of having a positive PSQI score increased by a factor of 8.246 (p-value = 0.000). This statistically significant finding suggests that individuals with higher GAD scores are significantly more likely to have a positive PSQI score.

The effect of nationality on PSQI, however, was not statistically significant (p-value = 0.126). While the Exp (B) value of 6.019 suggests a possible positive association, more data or a stronger effect size may be necessary for confirmation. The constant term (−0.866) represents the model's intercept and does not hold direct meaning in the context of PSQI.

The Cox & Snell R-squared value of 0.238 indicates that the logistic regression model explains approximately 24% of the variance in predicting positive PSQI scores. While this does not necessarily imply a "good" fit (as the benchmark for goodness-of-fit can vary by field), it suggests the model provides a moderate level of explanation for PSQI based on GAD and nationality. It is important to consider additional goodness-of-fit measures and potentially explore including more explanatory variables to improve the model's predictive power.

In conclusion, this study highlights a strong positive association between GAD and PSQI, suggesting that individuals with GAD are more likely to have a positive PSQI score. The influence of nationality remains inconclusive and warrants further investigation.

4 Discussion

4.1 Main findings

This study aimed to evaluate the emotional status of medical front line workers that were assigned to the COVID-19 field hospital in the Sultanate of Oman with the use of surveys. The 'emotional status' of HCWs was evaluated by quantifying the level of subjective depression, anxiety and the general quality of sleep experienced by HCWs. Participants in the study were HCW and were inclusive of "medical" (physicians and nurses) and "nonmedical" personnel (allied health professionals, pharmacists, and technicians).

Similar to studies from Saudi Arabia, Iran and Turkey, the present study found that the majority of the sample did not present with features that indicated depression, anxiety, or poor quality of sleep as a result of their work in the field hospital (35, 36). This finding aligns with existing literature globally and from the Arab region that have found that HCWs possess resilience and may not succumb to overwhelming distress during times of crisis (37). While it has been largely reported that the prevalence of anxiety disorders and depression are higher among HCWs during the COVID-19 pandemic, it is possible that scores in the present study might be attributed to mental preparedness as a result of emerging literature globally at the time and the infection control measures that were in place at the field hospital in Oman (38). Studies have suggested multiple protective factors that impact one's perception of the work environment, thereby enhancing resilience (39). Some of these factors include teamwork, acts of appreciation, dependability, dedication to the job, emotional support, and self-efficacy (40, 41).

In addition to accounting for potential confounding variables such as marital status and socio-economic status, the present study also identified a significant association between the duration of employment in the field hospital and the level of anxiety experienced by HCWs. Specifically, HCWs who had been employed at the field hospital for less than 5 months exhibited higher levels of anxiety compared to those who had been employed for longer durations. These findings are consistent with previous research suggesting that prolonged work exposure, lengthy working hours, sense of urgency, and increased workload can contribute to symptoms of burnout among HCWs (42–44). However, more recent data has emerged highlighting the resilience of HCWs and their ability to adapt to challenging situations (25). It is possible that the present study's findings reflect this resilience, with HCWs becoming more emotionally resilient over time as they adjust to their work environment and develop coping strategies. Further research is needed to better understand the protective factors that contribute to HCWs' resilience and ability to cope with challenging work environments, as this knowledge can inform decision-making and

interventions aimed at protecting the well-being of HCWs during global health emergencies such as the COVID-19 pandemic.

In addition, prolonged stress or anxiety response in the data suggested a higher risk of poor quality of sleep. This has been reflected in findings from studies emerging from Austria (45), Turkey (46), and Italy (47) which all demonstrated that elevated and prolonged levels of stress and anxiety are associated with poorer sleep quality. Interestingly, in contrast to these studies, the present study reported minimal impact on HCWs quality of sleep as a result of 'pandemic fatigue'. A study from the Philippines (48) found similar results among nurses that worked directly with COVID-19 patients. The implementation of safety protocols, increased vaccination regulations, and a positive outlook toward clinical resources are likely to contribute to lower levels of pandemic fatigue and more adequate sleep quality among medical frontliners.

Despite the increase in stressors and psychological vulnerability during the peak of the pandemic in 2020 within Oman, the findings of the current study are consistent with studies of resilience among medical HCW globally as the situation developed. While the events may be considered 'traumatic', trauma may not always yield a negative outcome, and this is subjective to the protective factors and personal resources that one is given access to at the time. Authors from a study in Madrid identified that resilience was vital to the psychological safety of HCW and enables them to cope with the increasing pressures of the role (49). The full extent of the psychological and physical toll that this pandemic may have had on the HCWs is yet to be fully understood. The findings of the present study have shed light on the enhanced emotional resilience of HCWs that were on the frontlines of the COVID-19 pandemic in the Sultanate of Oman. Further research into the protective factors and psychological status of the HCW would be helpful as it can inform governmental decision-making and further protect the welfare of HCW, whose role is vital during global health emergencies such as the COVID-19 pandemic.

4.2 Limitations and strengths

The findings of the study must be interpreted with caution as there are several limitations to consider, which highlight the need for further investigation. The data was gathered using self-reported questionnaires which are not the most reliable source of data collection; hence, the responses are subject to biases, and they were not verified against medical records. Furthermore, the responses may be subject to the interpretation of distress based on cultural and ethnic backgrounds. In the present study, the sample comprised of HCWs who were both medical and non-medical personnel which may differ in terms of exposure to the virus and being in first contact with COVID-19 patients. Medical personnel have different responsibilities to non-medical personnel and may be more overwhelmed by their duties compared to non-medical personnel. The sample was not analyzed separately which may have influenced the results. A larger sample may have yielded more accurate and reliable results. Furthermore, additional background variables such as prior history of mental illness could have further informed the findings in this study.

However, a significant strength of this study is that it is one of the few studies conducted on HCWs working in field hospitals, which is a unique and challenging environment. Additionally, the study contributes to the growing body of literature on the impact of the COVID-19 pandemic on HCWs' mental health and well-being. Moreover, the study's findings highlight the enhanced emotional resilience of HCWs in Oman, which is an important factor in managing the increasing pressures of their role during global health emergencies. Lastly, the study provides insights into the protective factors that can help HCWs cope with the psychological and physical toll of their work.

To address the limitations of the present study, future research could employ more objective measures of stress and anxiety, such as physiological indicators or clinician diagnoses, to validate the self-reported data. In addition, future studies could address the limitations of this study by using more objective measures of data collection such as medical records or biomarkers to confirm the self-reported results and also utilize the qualitative methodology to identify more robust data. Additionally, analyzing medical and non-medical personnel separately to explore any differences in their experiences. Future studies could also explore the long-term effects of the pandemic on HCWs' mental health and well-being, as well as the role of organizational support and resources in promoting resilience among HCWs.

5 Conclusion

To our knowledge, this study is the first to evaluate the emotional status of HCWs from a field hospital in the Sultanate of Oman. The findings of this study have presented the opportunity for further follow-up studies to evaluate any long-term psychological impact of the pandemic. Furthermore, this study underscores the global resilience observed among healthcare workers, prompting a call for further examination into the role of socio-cultural phenomena. Exploring the impact of factors such as strong family ties, religious views, effective leadership, and community cohesion on the resilience of healthcare workers could offer valuable insights. Evaluating how these elements contribute to their ability to cope with stress and challenging work environments can provide valuable insights. Such insights can guide policymakers in reinforcing these protective factors to better support healthcare workers in any future incidents of public health crises.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Health Studies and Research Approval Committee (HSRAC), Ministry of Health Oman, proposal ID: MoH/CSR/22/26365. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

RM: Writing – review & editing, Writing – original draft, Conceptualization, Data curation, Investigation, Methodology. HA-S: Writing – original draft, Writing – review & editing, Conceptualization, Methodology. NA-K: Writing – original draft, Writing – review &

editing, Conceptualization, Investigation. SR: Writing – original draft, Writing – review & editing, Project administration, Supervision. RB: Writing – review & editing, Writing – original draft, Data curation, Formal analysis, Methodology. NA-L: Writing – review & editing, Methodology, Supervision. MR: Writing – review & editing, Project administration. KA-R: Writing – review & editing. AM: Writing – original draft, Writing – review & editing, Formal analysis, Methodology, Software.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Environmental and geographical factors influencing the spread of SARS-CoV-2 over 2 years: a fine-scale spatiotemporal analysis

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Introduction: Since its emergence in late 2019, the SARS-CoV-2 virus has led to a global health crisis, affecting millions and reshaping societies and economies worldwide. Investigating the determinants of SARS-CoV-2 diffusion and their spatiotemporal dynamics at high spatial resolution is critical for public health and policymaking.

Methods: This study analyses 194,682 georeferenced SARS-CoV-2 RT-PCR tests from March 2020 and April 2022 in the canton of Vaud, Switzerland. We characterized five distinct pandemic periods using metrics of spatial and temporal clustering like inverse Shannon entropy, the Hoover index, Lloyd's index of mean crowding, and the modified space–time DBSCAN algorithm. We assessed the demographic, socioeconomic, and environmental factors contributing to cluster persistence during each period using eXtreme Gradient Boosting (XGBoost) and SHapley Additive exPlanations (SHAP), to consider non-linear and spatial effects.

Results: Our findings reveal important variations in the spatial and temporal clustering of cases. Notably, areas with flatter epidemics had higher total attack rate. Air pollution emerged as a factor showing a consistent positive association with higher cluster persistence, substantiated by both immission models and, to a lesser extent, tropospheric NO_2 estimations. Factors including population density, testing rates, and geographical coordinates, also showed important positive associations with higher cluster persistence. The socioeconomic index showed no significant contribution to cluster persistence, suggesting its limited role in the observed dynamics, which warrants further research.

Discussion: Overall, the determinants of cluster persistence remained across the study periods. These findings highlight the need for effective air quality management strategies to mitigate air pollution's adverse impacts on public health, particularly in the context of respiratory viral diseases like COVID-19.

KEYWORDS

SARS-CoV-2, sociodemographic and environmental determinants, air pollution, spatial modeling, machine learning, geoAI, remote sensing, spatial epidemiology

Highlights

- High spatiotemporal resolution study of SARS-CoV-2 influencing spread over 2 years.
- Areas with flatter epidemics have higher total attack rates.
- Air pollution is positively associated with SARS-CoV-2 cluster persistence.
- No significant link between socioeconomic index and cluster persistence.
- Factors influencing SARS-CoV-2 spread are stable across periods.

Introduction

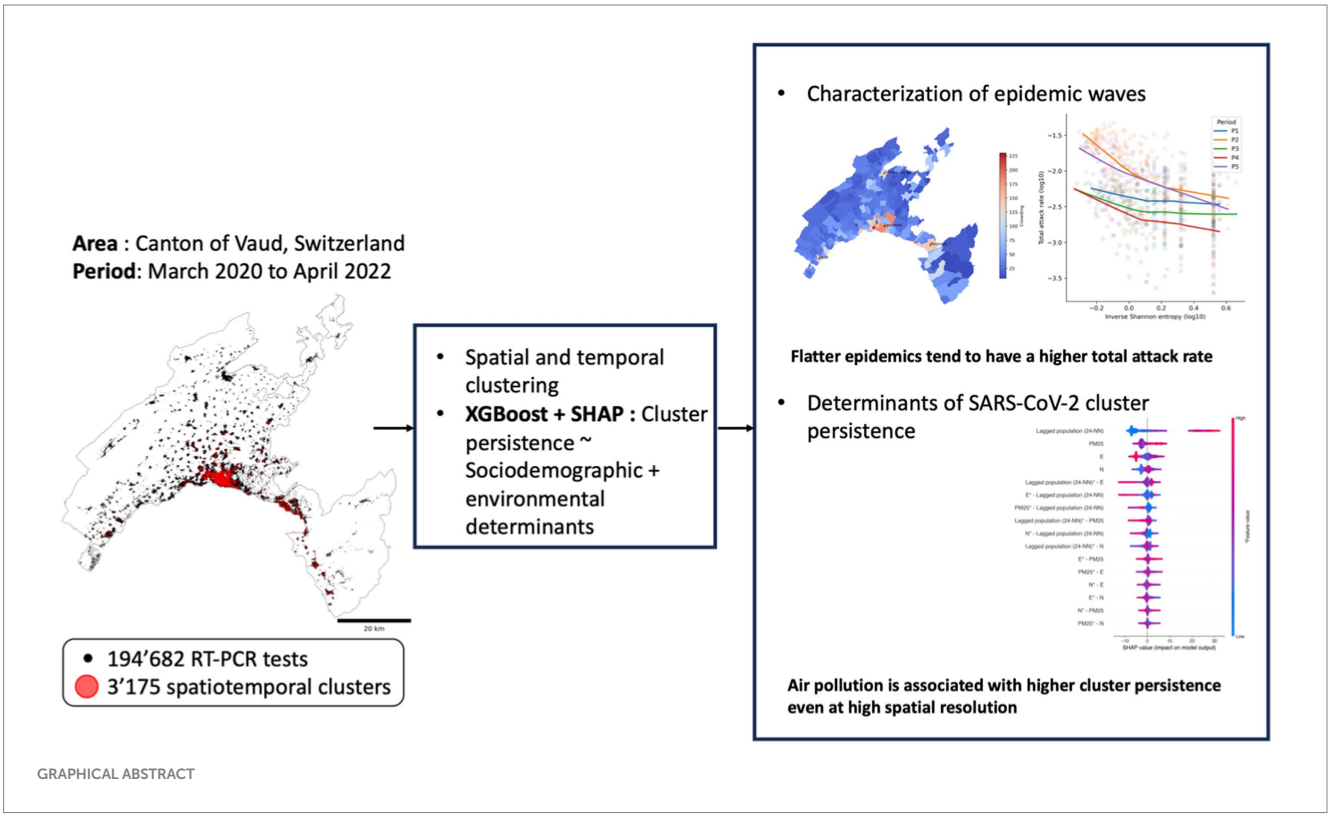
The SARS-CoV-2 pandemic has had a significant impact on the world's population and understanding the spatial and temporal patterns of its spread and its evolution is crucial for epidemic surveillance and control (1–5). Techniques such as hot-spot analysis, spatiotemporal clustering, and space–time scan statistics have been widely employed to analyze georeferenced data from SARS-CoV-2 RT-PCR testing (6–11). These analyses have revealed that the incidence and the mortality of the disease are not evenly distributed but rather cluster in certain areas and peak at certain times, indicating a high degree of heterogeneity in the diffusion dynamics of the virus (12–14).

To further understand the factors driving these patterns and disparities, subsequent research using methods such as regression modeling has provided better insights into the potential demographic, socioeconomic, and environmental determinants of the virus's spread (7, 15–18). This research conducted since the beginning of the pandemic and over more than 2 years has revealed the complexity of the issue, highlighting the intricate and interconnected array of factors influencing the spread of the virus at different geographical and temporal scales.

Human mobility, connectivity, and transportation have been identified as key factors facilitating the virus' spread (14, 19–22). Additionally, other reports have emphasized the importance of socioeconomic conditions, with socioeconomically deprived populations facing higher rates of exposure, incidence, and mortality (7, 23–25). These associations have been found to hold even at very local scales, highlighting the critical need to allocate more resources for pandemic recovery efforts on vulnerable populations as they are at higher risk of facing a syndemic rather than a pandemic (7, 26, 27). Additionally, studies have suggested that environmental factors such as air pollution and atmospheric conditions may play a significant role in the transmission of the virus (17, 28–31). "Indeed, exposure to air pollutants from both human-related emissions and natural events, such as particulate pollution and desert dust, can contribute to an increased diffusion of the virus" (17, 28–31).

Besides investigating the factors influencing the spread of SARS-CoV-2, research efforts have also been focused on understanding the patterns and intrinsic characteristics of the different waves of the pandemic. For instance, a study by Rader et al. (13) found that the peakedness of COVID-19 epidemics was influenced by population aggregation and heterogeneity. Specifically, the study found that epidemics in crowded cities were more spread over time and exhibited larger total attack rates compared to less populated cities.

Our study aims to analyze the various spatiotemporal factors influencing the spread of SARS-CoV-2 and examine how their impact may have evolved between March 2020 and April 2022. SARS-CoV-2 RT-PCR testing data georeferenced at a fine geographical scale over the canton of Vaud in Switzerland provide geolocated epidemiological



GRAPHICAL ABSTRACT

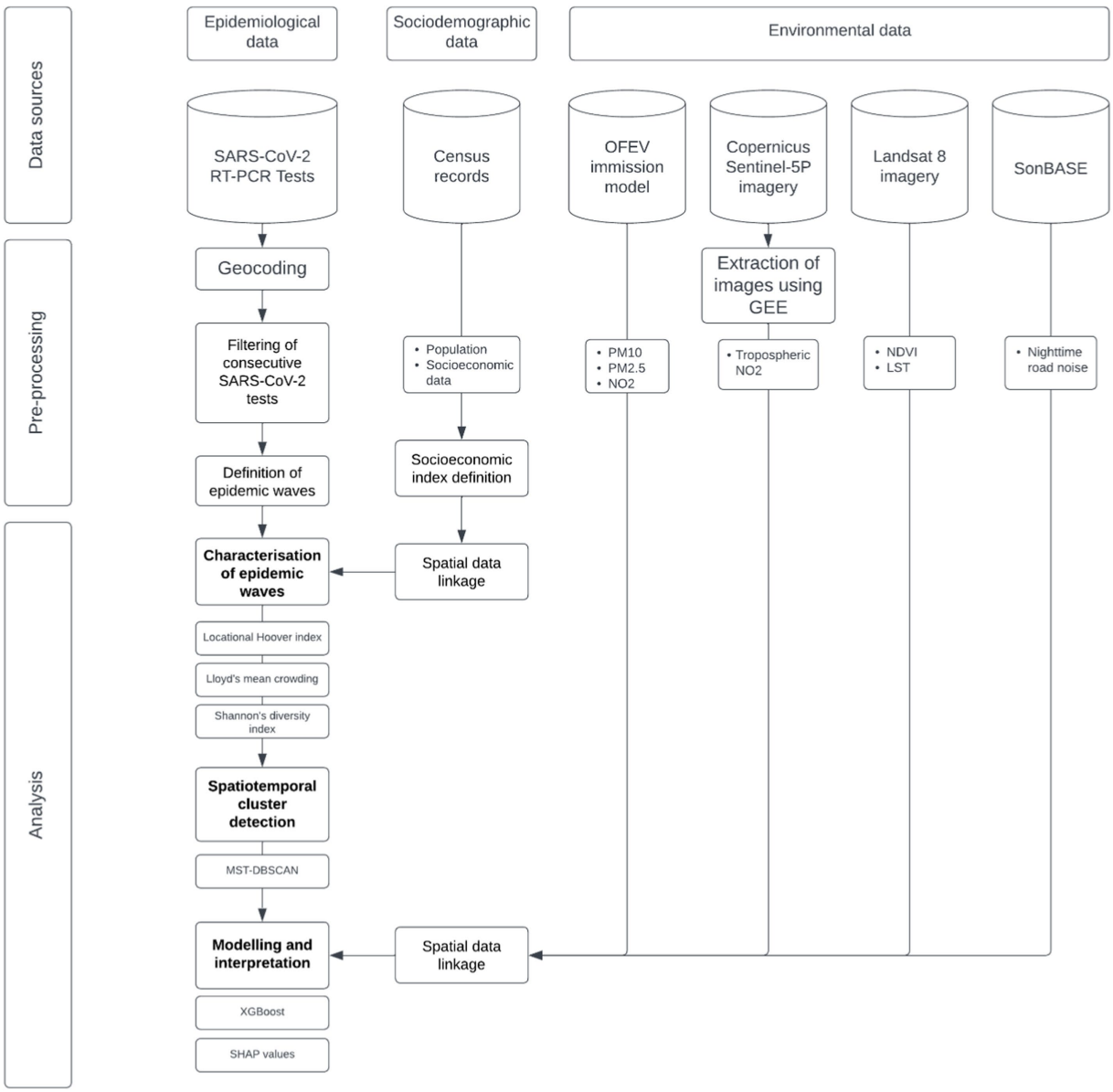


FIGURE 1
Flowchart of the study methodology. This chart outlines the approach used in our study, depicting the progression from data collection through to analysis. It highlights our data sources, including epidemiological, sociodemographic, and environmental datasets, and describes the sequential data processing operations. The methodology culminates in a modeling phase employing XGBoost, followed by an interpretative analysis using SHAP values to uncover the influence of the various factors on the diffusion dynamics and geographic patterns of SARS-CoV-2.

time series data on COVID-19 within various geographical settings (i.e., municipalities and hectares). It offers an unpreceded opportunity to assess the influence of local factors in determining epidemic behaviors. Indeed, employing high spatial resolution data may provide insights into local variations that would be indiscernible at coarser geographic scales. The enhanced granularity could help inform local policies, targeting public health interventions where most needed and finely tuning them to fit the specific conditions and needs of the affected communities, thereby allowing for better resource allocation (6, 11, 32). We investigate an extensive range of sociodemographic and environmental factors that may influence the diffusion dynamics and geographical patterns of SARS-CoV-2 using advanced spatial and analytical methods. This geospatial approach also helps to address some of the shortcomings of previous studies such as the use of broader geographical scale and the use of models that do not consider spatial effects.

Materials and methods

Figure 1 depicts the study's methodological workflow, illustrating the data sources, pre-processing operations, and analyses.

Data sources and preprocessing

COVID-19 testing and case data were obtained from the Institute of Microbiology (Lausanne University Hospital, CHUV). Data on

socioeconomic factors, air pollution (PM10, NO_2), noise pollution, vegetation (The normalized Difference Vegetation Index—NDVI), temperature (Land Surface Temperature—LST), population density at the hectare level, and population density around each hectare were collected from various sources, including census records, satellite imagery, and air and noise pollution immission models. All datasets were preprocessed to ensure compatibility.

Geocoding of the residential addresses

We geocoded the residential addresses of individuals who were tested for SARS-CoV-2 using an in-house offline procedure based on a Gestalt string matching algorithm. This algorithm was chosen for its robustness in handling a variety of misspellings and inconsistencies in address formats (33). This algorithm matches each residential address against a comprehensive dataset of all existing addresses in the canton of Vaud. The match exhibiting the highest level of similarity was then retained if the similarity was above 80% (n = 241,775, 85.4%). An 80% similarity threshold was set based on preliminary analyses that demonstrated a balance between match accuracy and inclusion of valid addresses. In total, 41,360 tests were not geocoded for various reasons. First, individuals residing outside of the study area, namely beyond the canton of Vaud or in other countries, were not included in the analysis (n = 31,506, 11.1%). This exclusion does not impact our analysis, as these tests fall outside our study scope. Second, a further group whose residential address could not be geocoded was also omitted (n = 9,854, 3.5%). Finally, in instances where the street number was missing, the addresses were geolocated at the centroid of the street (n = 5,918, 2.4%).

Filtering of consecutive SARS-CoV-2 tests

To accurately assess the incidence of SARS-CoV-2 infection in the study population, we filtered out consecutive RT-PCR tests performed within 20 days (n = 47,093, 19.5%). This prevented repeated testing of recent positive cases and emphasized unique infections. This approach helped ensuring that the dataset accurately represented distinct SARS-CoV-2 infections throughout the study. The final dataset comprised a total of 194,682 tests.

Defining epidemic periods

The SARS-CoV-2 pandemic has undergone multiple waves and mutations of the virus, affecting transmission rates and testing outcomes. We divided our dataset into five periods representative of the five major epidemic waves to analyze their impacts: the initial outbreak of the pandemic in early 2020 (Period 1, Feb 3, 2020–June 30, 2020), the second wave that occurred later that year (Period 2, July 1, 2020–Dec 15, 2020), the third wave in early 2021 (Period 3, Dec 16, 2020–May 7, 2021), the arrival of the severe Delta variant (Period 4, May 8, 2021–Nov 28, 2021), and the highly transmissible Omicron variant emergence (Period 5, Nov 29, 2021–April 15, 2022). This division allowed us to evaluate the characteristics of each wave and the potential evolution of the determinants of diffusion.

SARS-CoV-2 RT-PCR testing data

Our analyses included 41,672 positive SARS-CoV-2 RT-PCR tests from a total of 283,135 tests administered to 138,774 residents of the canton of Vaud (population 800,000), Switzerland, between March 2, 2020, and April 15, 2022. The testing procedure relied only on quantitative real-time PCRs and has been described in detail in previous studies (8, 10). The study received approval from the Cantonal Research Ethics Commission of Vaud (CER-VD), Switzerland (n°2020-01302).

Sociodemographic data

Demographic data used in this study were obtained from the Swiss Federal Population and Household statistics (34), which provides detailed information on the population at the hectometric scale. This data include population counts and demographic characteristics. This data were used to provide an accurate picture of the population distribution in the study area.

We calculated a socioeconomic deprivation index at the hectare level, using socioeconomic data at the hectometric scale[1] and a methodology developed by Lalloué et al. (35), which has been previously used in studies investigating socioeconomic disparities in health (7, 36). This methodology involves a series of principal component analyses to identify and remove redundant variables, select key variables of interest, and combine them into a single index that reflects socioeconomic deprivation (35). The socioeconomic index was normalized to a scale ranging from 0 to 1, where a value of 0 represents the highest level of socioeconomic deprivation, and a value of 1 denotes the lowest level of deprivation. This standardization facilitates a more intuitive interpretation of the index, aligning higher values with less deprivation.

Environmental data

Six environmental variables that represent the living environment of the population were considered: nighttime road noise, a vegetation index (NDVI), an estimate of ground surface temperature (LST) and air pollution markers (NO_2, PM10, PM2.5). These factors help identify areas with conditions potentially promoting transmission. Nighttime road noise data were produced by the Swiss Federal Office for the Environment (OFEV) and compiled in the SonBASE database (37), served as a proxy for urban density and road traffic activity. Nighttime noise was selected as it represents the longest exposure at the residential address. This database provides a value in dB(A) for the whole territory with a resolution of 10 m. From these values, we calculated the average nighttime car noise value for each populated hectare of the Vaud territory.

The normalized difference vegetation index (NDVI) and land surface temperature (LST) were derived from Landsat 8 satellite images of the Lake Geneva region, taken during the summer of 2021 (20.07.2021) (38). The NDVI is a satellite-derived measure indicating the presence and condition of vegetation, with higher values signifying healthier vegetation while LST measures the heat radiated by land surfaces, also derived from satellite data, informing studies on urban heat islands. Both these indices serve as critical environmental variables to quantify local variations in temperature, humidity, and urbanicity levels (39, 40).

Air pollution data were obtained from two sources. First, 2020 Meteotest's immission model commissioned by the OFEV (41) provided information about air pollution levels (NO_2, PM10, PM2.5) at a 20-m resolution. Despite being anterior the COVID-19 pandemic, the immission model provide valuable information on the baseline conditions and long-term exposure to air pollutants in the study area. Second, to account for short-term exposure air pollution, daily

1 www.microgis.ch

nitrogen dioxide (NO_2) levels were obtained from satellite imagery via Google Earth Engine (42). To obtain daily average tropospheric NO_2 concentrations, we extracted and processed Sentinel-5 Precursor imagery ($3.5 \times 7\,km^2$ spatial resolution) using algorithms adapted from Ghasempour et al. (43). We aggregated the daily average concentrations by month resulting in a time-series of monthly tropospheric NO_2 concentrations with comprehensive coverage of the study area during the study period.

Characterization of the epidemic waves

Three indices were calculated for each epidemic period and municipality of the canton of Vaud: the Inverse Shannon entropy index to evaluate the temporal clustering of cases, Lloyd's index of mean crowding to understand population structure, and the Hoover index to compare the spatial distribution of the population to the spatial distribution of COVID-19 cases.

Inverse Shannon entropy

To evaluate how temporally clustered COVID-19 cases are within each municipality, we used the Shannon diversity index. For a specific municipality, we established the incidence distribution as the ratio of COVID-19 cases *j* taking place on day *i*. The Shannon index, represented by (1) is based on the disease incidence curve for each location, making it less susceptible to variations in reporting rates across municipalities.

$$-\left(\sum\left(p_{ij} * \log\left(p_{ij}\right)\right)\right)^{-1} \quad (1)$$

The index achieves its highest value when all cases occur on 1 day and its lowest value when the epidemic has an equal number of cases on each day.

Locational Hoover index

The Hoover index is a widely used measure to assess trends of concentration in the distribution of a population. To evaluate the progressive spread of COVID-19 cases, we used the locational Hoover index, which measures spatial imbalance between two variables in a given geographic area (44). It compares the proportion of the municipality's total population residing in a particular hectare to the proportion of COVID-19 cases occurring in that same hectare during a specific time period. This provides a way to understand whether COVID-19 cases are clustered in certain areas or distributed more evenly throughout the municipality. Values closer to 100 indicate concentration in few hectares, while those close to zero suggest a more homogeneous spreading (44). In cases where a hectare intersected with multiple municipalities, it was assigned to the municipality having the larger population.

Lloyd's mean crowding

To better understand differences in population structure across municipalities, we employed the Lloyd's index of mean crowding (45), considering each hectare's population count within each municipality. Higher values of Lloyd's index indicate a more spatially clustered population structure while lower values indicate a population structure that is more evenly distributed.

Spatiotemporal cluster detection

To monitor and analyze the spatiotemporal patterns of SARS-CoV-2 diffusion, we used the MST-DBSCAN (modified space–time density-based spatial clustering with application with noise) algorithm (46). This method, a modified version of the well-established DBSCAN algorithm, identifies clusters of arbitrary shapes and is adept at capturing complex patterns irrespective of administrative boundaries (47). The settings we used included a spatial distance of 200 m, a minimum period value of 1 day, and a maximum period value of 14 days.

Utilizing the MST-DBSCAN algorithm, we investigated the spatial and temporal variations in the dynamics of COVID-19 waves. This allowed us to identify and monitor spatiotemporal clusters throughout the study period based on spatial and temporal proximity (45, 47). Importantly, it enabled us to monitor cluster persistence.

Cluster persistence

Cluster persistence, defined as the duration from the emergence to the disappearance of a cluster, was analyzed to understand diffusion dynamics and pinpoint areas with prolonged persistence (7). While clusters identified through MST-DBSCAN can take arbitrary shapes, we projected them onto the populated hectares in the canton of Vaud to capture the duration each hectare remained within a cluster. Hectares experiencing multiple cluster episodes (i.e., repeated emergence and disappearance) were assigned the cumulative duration spent within a cluster.

Modeling

eXtreme gradient boosting

To evaluate the associations between cluster persistence and sociodemographic and environmental features, we employed the eXtreme Gradient Boosting (XGBoost), a widely popular machine learning algorithm that has been used in many supervised classification and regression applications (48–50), including for COVID-19 research (51, 52). XGBoost is a gradient boosting algorithm that iteratively ensembles decision trees using gradient descent algorithm to minimize model error (53).

We assessed multicollinearity using the Variance Inflation Factor (VIF), considering values above 10 to indicate high multicollinearity. To mitigate issues of multicollinearity, we combined Land Surface Temperature, NDVI, and Nighttime car noise into an "Urban type index" using principal component analysis. Similarly, an "Air pollution index" was derived from the three measures of air pollution provided by the immission model: NO2, PM10, and PM2.5. To further prevent multicollinearity, the air pollution and the socioeconomic deprivation indices were evaluated in separate models.

Given the significant spatial autocorrelation in the distribution of cluster persistence (Supplementary Figure S1, Moran's $I = 0.95$, $p < 0.001$), we incorporated geographic coordinates of each hectare's centroid into the multivariable models to capture these spatial dependencies. XGBoost models that include geographic coordinates have been shown to adequately capture spatial effects (i.e., spatial autocorrelation and spatial heterogeneity) when compared to classical

statistical spatial modeling methods such as the spatial lag model and the Multiscale Geographically Weighted Regression (MGWR); these spatial effects being captured through the coordinates themselves, their interaction (longitude * latitude) and the interaction between coordinates and non-spatial features (54).

In addition, machine-learning approaches like XGBoost generally require fewer assumptions about the underlying processes and perform well at identifying patterns in large datasets with complex nonlinear interactions (55). In comparison, model selection in spatial modeling can be computationally challenging, particularly due to the need for additional calculations such as fitting local regression at each location (54).

One limitation of XGBoost is that it can be difficult to interpret the importance of individual features in the model. To improve interpretability, we used SHapley Additive exPlanations (SHAP), an effective interpretability technique for machine learning models (56). SHAP is a game-theoretic approach that assigns to each model feature a numerical value that represents its contribution to the final prediction. This allows for a transparent understanding of how the model provides predictions. This is particularly important for epidemiology and public health applications where interpretability is critical. However, it should be noted that SHAP values, unlike coefficients in a regression model, represent partial dependence. They characterize the contribution of a specific feature to the difference between the actual prediction and the mean prediction while accounting for other factors in the model (56). This distinction is crucial, as SHAP values provide a more nuanced understanding of the relationships between variables in our XGBoost models by considering complex interactions that may not be captured by traditional regression coefficients (57).

Anticipating the potential for reporting bias—due to variations in testing rates possibly leading to more reported cases—we adjusted for differences in testing rates across areas and time periods to account for these disparities across different areas and time frames. We determined the testing rate for each hectare by dividing the number of tests by the population and calculated rates for each time period to account for changing testing practices.

To estimate the XGBoost model's performance, the dataset was split into an 80% training and 20% testing partition. The model was trained on the training set, and its generalization capacity and predictive accuracy were assessed using the coefficient of determination (R^2) and root mean square error (RMSE) on the testing set. The hyperparameter optimization procedure is described in the Supplementary material Section S1: "Hyperparameter Optimization."

Following the primary analysis with XGBoost, we conducted a sensitivity analysis to further investigate the seemingly low influence of the SES index on cluster persistence.

Sensitivity analyses

Given the initial results suggesting a weak association between the SES index and cluster persistence, we sought to assess the robustness of our findings by replicating the methodologies from previous work (7), which demonstrated a significant association between socioeconomic status and cluster persistence. Consequently, we used a Cox Proportional Hazards (PH) model, adjusting for population density and testing rates to control for confounding.

Results

Description of the temporal and spatial clustering of COVID-19 cases

The time-series of SARS-CoV-2 RT-PCR testing data allows to track the weekly count of tests and positive cases across the study's five defined periods (Figure 2). Three distinct peaks emerged, corresponding to the main pandemic waves that have been documented in the Canton de Vaud. The first wave was observed during the onset of the pandemic, followed by a second wave in the last months of 2020 and a third peak linked to the Omicron variant in late 2021 and early 2022 (fifth period).

The second peak displayed the highest number of positive cases and volume of tests, indicative of a substantial surge in virus prevalence and testing capacity. The third period was characterized by a low positivity rate with moderate testing intensity (Supplementary Figure S2). The fourth period shows a decrease in both positive cases and test number. During the fifth period, the Omicron-associated peak underscored the emergence of this highly transmissible variant with a high positive rate of around ~50% (Figure 2; Supplementary Figure S2) reached around the end of January 2022.

The epidemic curves reveal distinct epidemic shapes across different geographical and temporal contexts, as shown when specifically looking at four major towns (Lausanne, Yverdon-les-Bains, Montreux, and Nyon) and five epidemics waves (Figure 3A). The most populated area of Vaud canton, the town of Lausanne (population ~ 140,000) exhibited the least peaked epidemics while the distribution of cases over time corresponds to the one of the cantons. The three other municipalities showed higher peakedness but distinct epidemic behaviors. Yverdon-les-Bains (YLB, pop. ~ 30,000) had a very high peak of cases during the first period and relatively low peak during the second period. In Montreux (pop. ~ 26,000), cases were mostly concentrated in the second period with only a little fraction distributed in the first and fifth period while in Nyon (pop. ~ 22,500) cases were mostly distributed among the two first periods with a very low fraction present in the fifth. These two smaller cities also have in common the almost complete absence of cases during the fourth period.

Descriptive statistics provided more information on the different transmission dynamics. The Inverse Shannon entropy index values for the first, and third periods were almost equal at 0.24, and 0.22, respectively (Table 1). The fourth period showed the highest peakedness (0.29) while the second and fifth periods showed the lowest values at 0.14 and 0.16, respectively (Table 1). The total attack rate in each municipality was negatively correlated with the inverse Shannon entropy index in each period suggesting that flatter epidemics (i.e., less peaked) have a higher total attack rate (Figure 3B). We observed shared patterns between periods 1, 3, and 4; exhibiting a flatter profile and between periods 2 and 5 that have a steeper slope. The LOWESS curves suggest a negative relationship that tends to attenuate at Shannon entropy index values (log-transformed) above 0 (Figure 3B). Lloyd's index of mean crowding provided valuable insights into the spatial structure of the population in each municipality taking into account both population density and how density is distributed. For instance, Montreux has a relatively lower

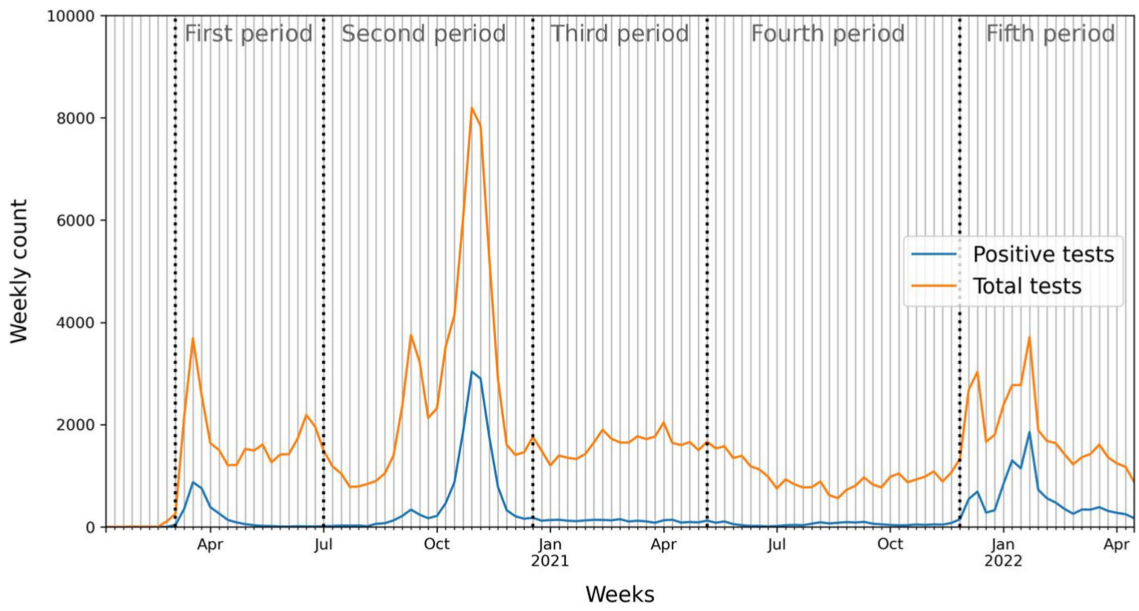


FIGURE 2
Weekly distribution of total SARS-CoV-2 RT-PCR tests and positive tests throughout the study period. Dotted lines correspond to the five defined periods.

population density compared to Nyon and YLB but exhibits a higher crowding value due to the patchiness of the distribution of its population (Figure 3C; Supplementary Figure S3).

Our analysis showed a strong correlation between population structure and the peakedness of the pandemic waves (Figure 4A). In densely populated urban areas, the crowding index was significantly higher and the peakedness lower compared to sparsely populated municipalities. The spatial distribution of the temporal clustering of cases for each period (Figure 4B) illustrates the wide variations of the Shannon index (scaled from 0 to 1) across different municipalities and periods.

The time-series analysis of the weekly locational Hoover index (%) and total positive cases, revealed that despite substantial differences in the number of weekly positive cases at the peak of periods 1 and 2, the locational Hoover index values for these two periods were strikingly similar (Figure 5A). This apparent paradox is likely due to different testing strategies, due to higher tests capacity during the second period. The locational Hoover index calculated for each period had median values of 86.5, 75.1, 81.8, 0, and 78.0 for the first, second, third, fourth, and fifth periods, respectively (Table 1). These findings suggest that the second period had the most homogeneous distribution of cases while the fourth period had the most unequal (i.e., spatially clustered) distribution of cases within the population. To gain more insight on it, we mapped the locational Hoover index across different periods, allowing for an easy comparison of the spatial patterns of case concentration (Figure 5B).

Spatiotemporal cluster detection and cluster persistence

The MST-DBSCAN analysis identified a total of 3,175 clusters with periods 2 and 5 exhibiting the highest number of clusters (Table 1). Figure 6 illustrates the emergence and disappearance of these clusters throughout the study period. Among the 3,175 clusters, 3,158 emerged and disappeared within the same period, while 17 overlapped between two periods (P1-P2: 1, P2-P3: 7, P3-P4: 3, and P4-P5: 6). The differences in median cluster persistence across periods were statistically significant (Table 1). Cluster persistence was positively associated with the number of positive RT-PCR tests from cluster emergence to disappearance (Pearson's $r = 0.36$, 95% confidence interval (CI), 0.33 to 0.36, $p < 0.01$) (Supplementary Figure S4). Additionally, the number of clusters persisting for more than 30 days varied considerably among the periods. Only two were present in period 1, while 28 emerged in period 2, none in periods 3 and 4, and 27 appeared in period five (Figure 6).

The spatial distribution of cluster persistence shown on the map reveals a pronounced concentration of longer-lasting clusters in urban areas, particularly around the city of Lausanne (Supplementary Figure S1). This pattern underscores the potential influence of higher population density and urban activity on the sustained transmission of SARS-CoV-2, factors that were considered in the subsequent modeling analyses.

Determinants of cluster persistence

Univariate analyses

We first conducted univariate XGBoost model analyses for each demographic, socioeconomic, and environmental feature independently and for the whole study period. This step involved fitting separate XGBoost models for each individual feature, which allowed us to explore the potential relationship between each feature and cluster persistence in isolation. This initial univariate analysis served as a preliminary assessment of the relevance and potential importance of each feature in predicting the outcome of interest. The

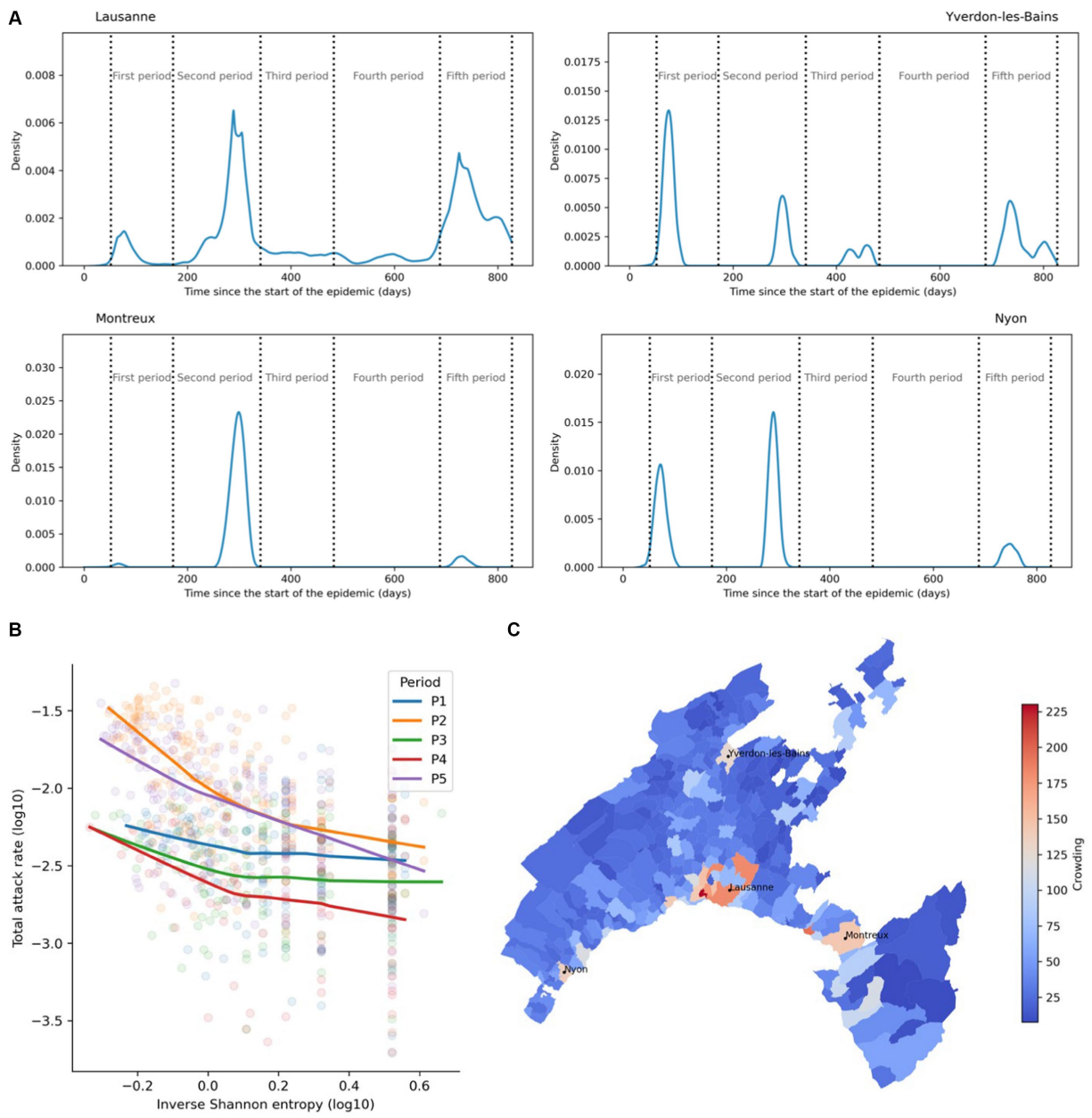


FIGURE 3
Epidemic curves, temporal clustering, and population structure. **(A)** Examples of epidemic curves across the study period for four municipalities of the canton and showing the percentage of the total cases happening on any given day. Lausanne and Yverdon-les-Bains (YLB) have less peaked epidemics than Montreux and Nyon. **(B)** Relationship between the Shannon index and the final attack rate for municipalities of the canton of Vaud and each period (p1 = first period, ..., p5 = fifth period). Lines correspond to LOWESS curves fitted for each period. **(C)** Lloyd's index of mean crowding for each municipality of the canton of Vaud.

following features were evaluated: population density (*Population*) in the hectare, population density in the surroundings (*Lagged population 200 m, Lagged population 8-NN, Lagged population 24-NN*), testing rate [*Testing rate (%)*], socioeconomic deprivation index (*SES index*), vegetation index (*NDVI*), the land surface temperature (*LST*), the nitrogen dioxide concentration (*NO_2*), the 10 and 2.5 microns or less particulate matter concentration (*PM10 and PM2.5*) extracted from the immission models (see section Data sources and preprocessing), the tropospheric NO_2 concentration average for each period [*Tropospheric NO_2 (periodic avg)*], the nighttime car noise (*Nighttime car noise*), and the longitude (*E*) and latitude (*N*). The lagged population 24-NN corresponds to the average population in the 24 nearest populated hectares. This number was chosen to match the radius of 200 m used in the MST-DBSCAN analysis used for spatiotemporal cluster detection and thus the cluster persistence definition.

While the three predictors capturing population density in the surroundings demonstrated strong performance, the "Lagged population (24-NN)" was the most promising predictor and was retained for the multivariable models. The "Testing rate (%)" presented

TABLE 1 Characteristics of the five periods.

Period	Overall	P1(First wave)	P2 (Second wave)	P3 (Third wave)	P4 (Delta)	P5 (Omicron)	*p*-value
Number of clusters	3,175	280	1,482	121	47	1,228	
Peakedness, median [Q1, Q3]	0.20 [0.09, 0.39]	0.24 [0.13, 0.39]	0.14 [0.08, 0.29]	0.22 [0.12, 0.40]	0.29 [0.13, 0.42]	0.16 [0.07, 0.31]	<0.001
Hoover index, median [Q1, Q3]	79.8 [0.0, 92.5]	86.5 [69.4, 94.5]	75.1 [50.1, 87.9]	81.8 [0.0, 93.8]	0 [0.0, 92.9]	78.0 [55.0, 91.4]	<0.001
Cluster persistence (days), median [Q1, Q3]	4 [2, 9]	6 [3, 10]	4 [2, 9]	5 [2, 9]	5 [2, 10]	4 [2, 9]	0.004
Number of positive tests, median [Q1, Q3]	1 [1, 3]	2 [1, 3]	2 [1, 4]	1 [1, 2]	1 [1, 3]	1 [1, 3]	0.518

Descriptive statistics, including number of clusters, peakedness, hoover index, cluster persistence, and number of positive tests of the pandemic overall and over the five different periods.

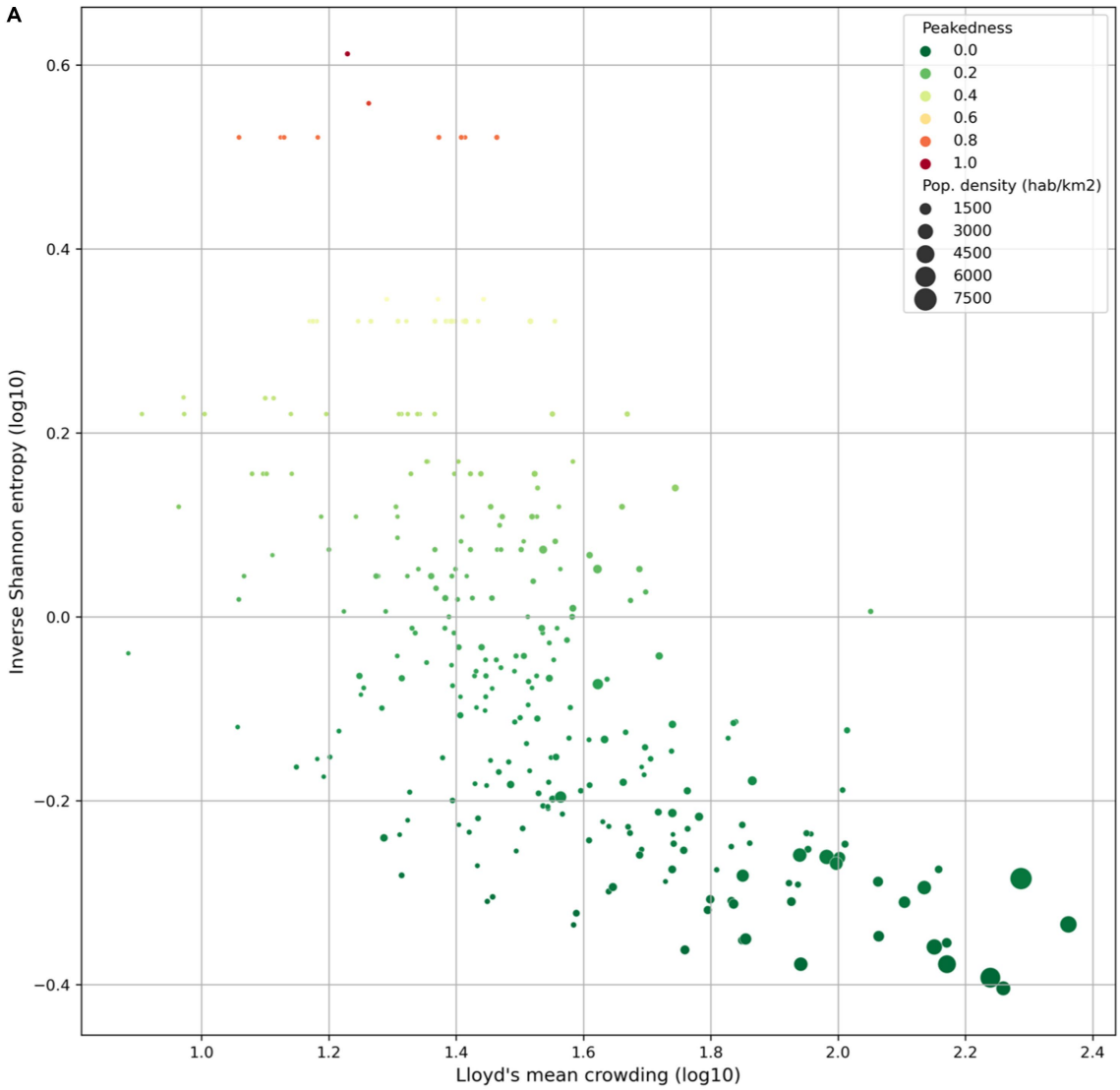


FIGURE 4 (Continued)

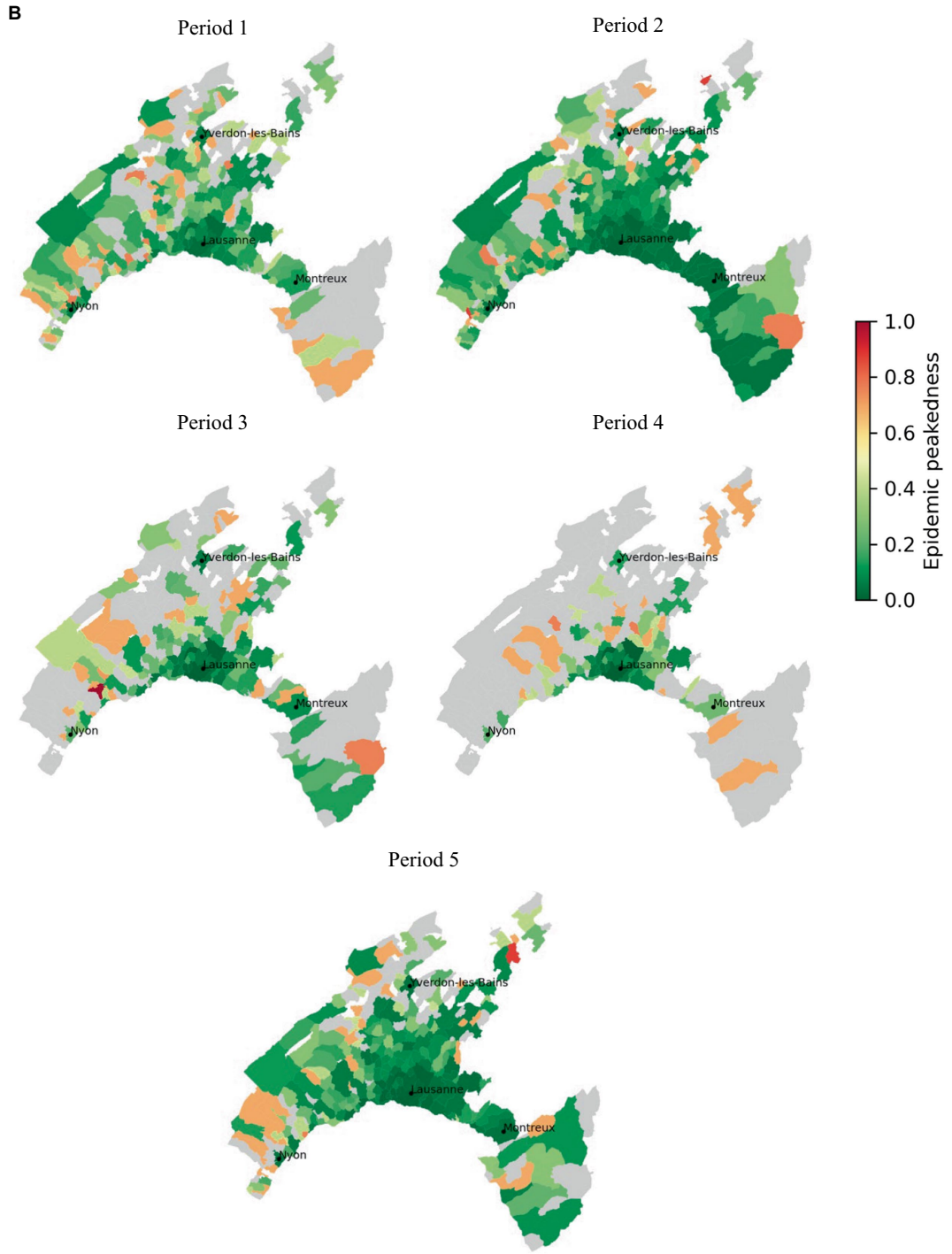


FIGURE 4
Population crowding and epidemic peakedness. **(A)** Relationship between the Shannon index and the Lloyd's index of mean crowding. **(B)** Maps of the Shannon index (scaled from 0 to 1) for each defined period of the study. Municipalities with no reported cases during a period are shown in gray.

a moderately high *F*-score of 1,402 and an R^2 value of 0.34, indicating the importance of adjusting for it in subsequent analyses. Air pollution features such as NO_2, tropospheric NO_2, PM2.5 and PM10 displayed reasonable *F*-scores, R^2 and, RMSE values, pointing to their usefulness in predicting cluster persistence (Table 2).

However, some features like SES index, NDVI, Nighttime car noise showed low R^2 values and limited predictive power. Interestingly, SES index has a high *F*-score of 1,900 but a negative R^2 value, suggesting that it may not contribute meaningfully to the model's explanatory power (Table 2). The sensitivity analyses evaluating the relationship between the SES index and cluster persistence revealed a significant association between the SES index and cluster persistence [Hazard Ratio (HR) = 0.49, $p < 0.005$], but a low Concordance index (C-index = 0.54), which is only

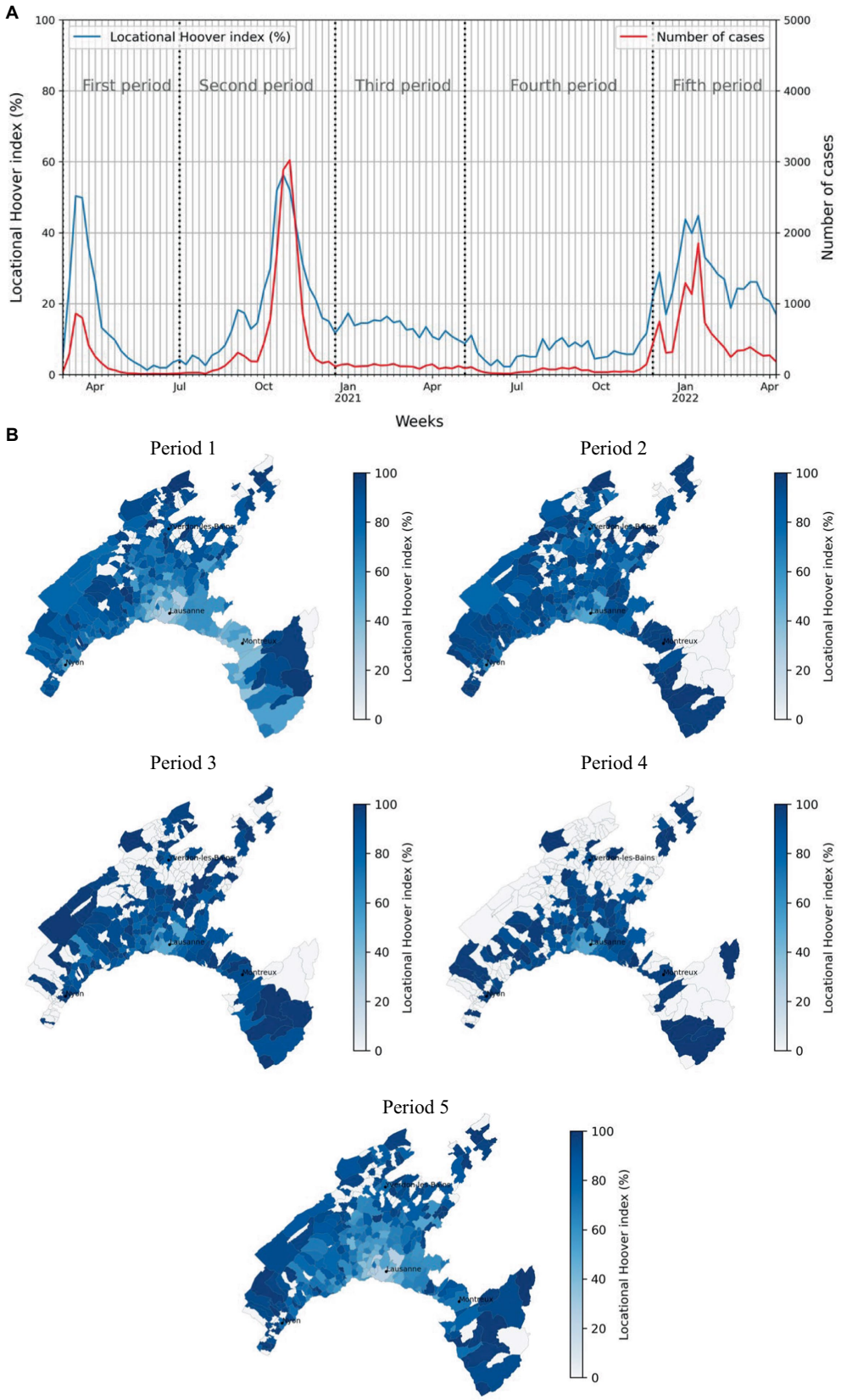


FIGURE 5
Locational Hoover index. **(A)** Weekly locational Hoover index over the study period. **(B)** Maps of the locational Hoover index for each defined period of the study. Values closer to 100 indicate concentration of SARS-CoV-2 cases in few hectares of the municipality, while those close to zero suggest a more homogeneous spreading of cases in the municipality.

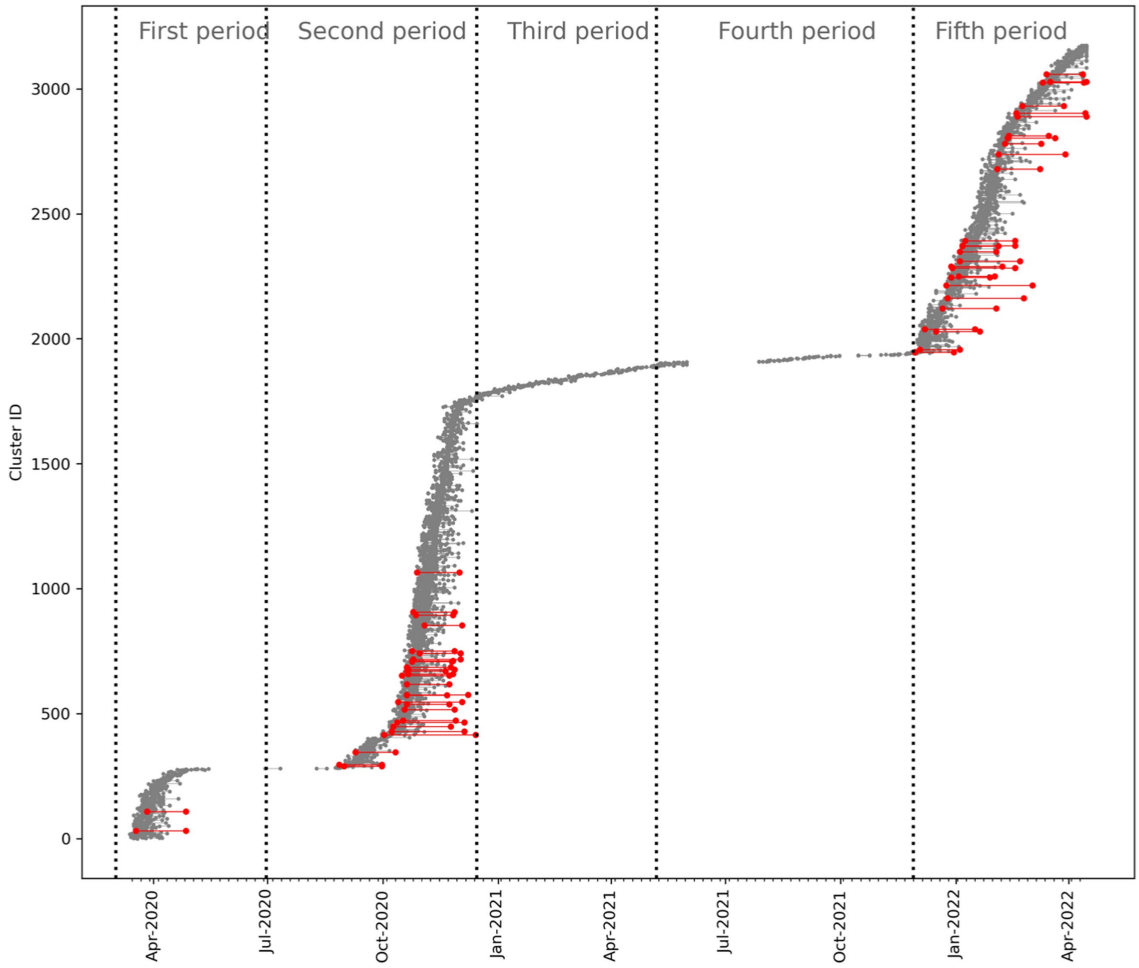


FIGURE 6
MST-DBSCAN clusters. Timeline of MST-DBSCAN clusters identified throughout the study period. Each cluster is indicated as a line going from the date of its emergence to the date of its disappearance. Clusters that persisted for more than 30 days are highlighted in red.

TABLE 2 **Overall model accuracy of the univariate XGBoost models.**

Feature	*F*-score	R^2	RMSE
Population	814	0.33	34
Lagged population (8-NN)	1,492	0.58	26.8
Lagged population (24-NN)	1,666	0.66	23.6
Lagged population (200 m)	1,709	0.57	27
Testing rate (%)	1,402	0.34	33.6
SES index	1,900	−0.03	42
NDVI	1,736	0.02	40.8
LST	1,830	0.03	40.9
NO_2	2,198	0.24	36.1
PM10	2,144	0.29	34.8
PM2.5	1,828	0.36	33.2
Tropospheric NO_2	1,796	0.2	37.1
Nighttime car noise	1,995	0.006	41.3
E	1,374	0.28	35.2
N	1,243	0.28	35

For each analyzed features, model's accuracy (*F*-score), the proportion of variance in the dependent variable that can be explained by the independent variable (R^2) and the root of the Mean Square Error (RMSE) are computed.

slightly better than a random guess (0.5), indicating limited predictive accuracy.

Finally, we complemented these results with multivariable models to account for potential interactions and combined effects of multiple features.

Multivariable analyses

We estimated the joint effect of all spatial and non-spatial features on cluster persistence by fitting separate multivariable XGBoost models corresponding to each period.

Supplementary Figure S5 shows the SHAP summary plots for the 16 top contributing features at each of the five periods. The lagged population was a key feature, highlighting the importance of adjusting for surrounding population density in our models. The location effects were also essential in the model, as illustrated by the range of SHAP values of the E and N geographic coordinates (Supplementary Figure S5). The contribution of the location effect on cluster persistence, measured by SHAP values of E and N is shown in Supplementary Figure S6. These display a clear spatial pattern with locations in red representing hectares contributing positively, while those in blue depict hectares with a negative impact. It is crucial to emphasize that these effects account for all other features in the model, highlighting the unique contribution to cluster persistence stemming only from the location effect. The areas with positive contribution on cluster persistence are mainly located in the urban area of Lausanne and to its East side.

Air pollution—captured by the air pollution index and tropospheric NO2—was an important feature in all periods (Supplementary Figure S5). In period 1, 3, and 5, the air pollution index was the most contributing features after the lagged population density. In period 2, the air pollution index was most important feature of the model. In period 4, tropospheric NO_2 had a great contribution to the model. The other features, the urban type and SES indices, and the testing rate, contributed only very slightly to the models. There were several interactions between spatial and non-spatial features but of relatively low contribution to the models. Regarding overall fit, R^2 and RMSE values are summarized in Supplementary Table S1.

In addition to the comprehensive XGBoost model incorporating all features, we also fitted separate models that focused on each air pollutant and on the SES index individually, along with location effects (E and N) and adjustments for population density ["Population" and "Lagged population (24-NN)"; Figure 7]. These analyses were conducted for the whole study period and specifically within the Lausanne urban area to ensure a purely urban context, avoiding potential residual confounding effects arising from urban versus rural comparisons. By conducting these separate analyses, we isolated the potential impact of each air pollutant on cluster persistence and examined their relationships with location and population density.

Across all air pollutants derived from the immission model, there was a clear pattern where higher concentrations were generally associated with higher cluster persistence. However, their relationships are non-linear and present a threshold at around 10.0 μg/m^3 for PM2.5 (Figure 7A), 14.0 μg/m^3 for PM10 (Figure 7B), and 16.0 μg/m^3 for NO_2 (Figure 7C). For PM10 and NO_2, these thresholds are below the annual average immission limit values defined by the Swiss Air Pollution Control Ordinance (i.e., 20 μg/m^3 for PM10 and 30 μg/m^3 for NO_2) (41). For PM2.5, the relationship's threshold was right at the annual average immission limit value of 10.0 μg/m^3. The relationship between tropospheric NO_2 was less clear with a slight positive relationship until 2.7 mol/m^2 followed by a negative relationship (Figure 7D), potentially due to the coarser spatial resolution.

In terms of variable importance, the analysis showed patterns similar to the multivariable models fitted for the whole study area and by period, with air pollutants showing a high contribution to the model and the SES and urban type indices showing a relatively modest contribution (Supplementary Figure S7).

Discussion

Summary of main findings

Our study examines the demographic, socioeconomic, and environmental determinants of SARS-CoV-2 diffusion and spatiotemporal dynamics at high spatial resolution. Most existing studies examine demographic (e.g., density, human mobility), socioeconomic, or environmental factors in isolation. Our work advances a more holistic approach by combining these variables with precisely geolocated SARS-CoV-2 testing data and advanced modeling techniques. Our main findings reveal a positive non-linear relationship between air pollution and cluster persistence with thresholds equal or below the annual average immission limit values for PM2.5, PM10, and NO_2. Additionally, we identified stable diffusion characteristics across periods and no significant contribution of the socioeconomic index to cluster persistence.

Comparison with existing literature

Our analysis using epidemic peakedness, Hoover index, and Lloyd's mean crowding reveals SARS-CoV-2's spatiotemporal diffusion dynamics, providing insights into case spatiotemporal distribution, population structure, and degree of clustering. While our findings on peakedness aligns with previous work conducted on influenza at the city-scale (58) and SARS-CoV-2 at the prefectural level in China (13), we were able to identify these patterns at much higher spatial resolution.

There is an ongoing debate about the association between air pollution, SARS-CoV-2 infection, and COVID-19 severity. While the study of this relationship is complex (59), several potential biological mechanisms underpinning these associations have been identified, ranging from air pollution's influence on the transport and viability of viral particles to its impact on the body's innate defense mechanisms and long-term immune function (60–62).

The relationship we identified between air pollution and cluster persistence is consistent with several studies in the literature that have reported associations between SARS-CoV-2 infection and COVID-19 severity, and mortality with both short and long-term exposure to air pollution (17, 18, 31). For example, a recent study conducted in Switzerland found an association between long-term exposure to air pollutants and COVID-19 severity and mortality, but only during the first major wave of the pandemic when the national health system was not fully prepared to face the virus (18). However, this study focused exclusively on severity and mortality, while our findings suggest a potential link between air pollution, an increased risk of SARS-CoV-2

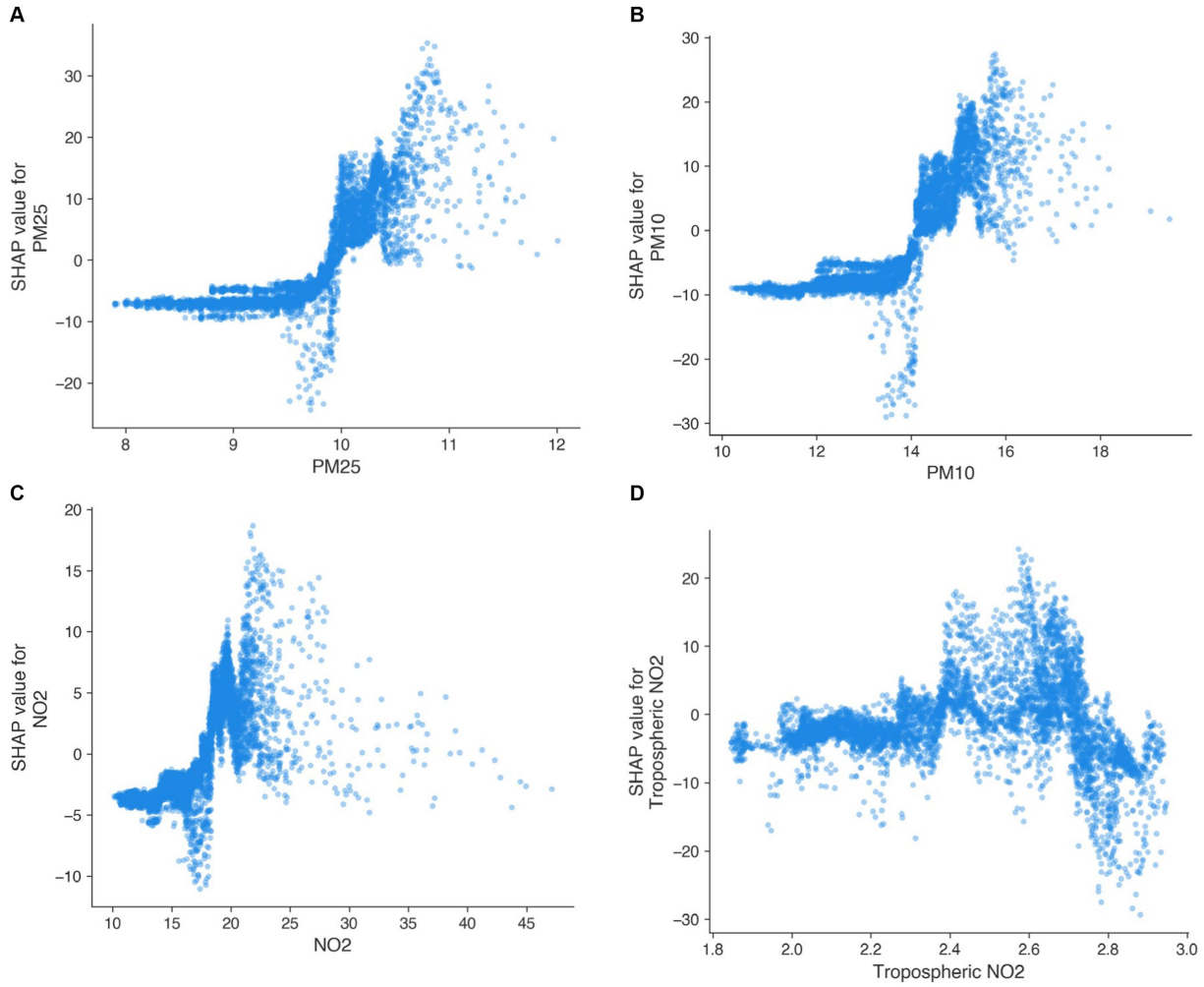


FIGURE 7
SHAP dependence plots showing the relationship between air pollutants and cluster persistence. **(A)** PM2.5, **(B)** PM10, **(C)** NO_2, and **(D)** Tropospheric NO_2.

infection and prolonged epidemics. In a recent nationwide cohort study in Denmark, Zhang et al. (63) found that individuals facing long-term exposure to air pollution were at an elevated risk of SARS-CoV-2 infection but did not consider the infection dynamics.

Notably, our study presents the advantage of identifying this association consistently over a two-year period and at a very high spatial resolution which reveals that nearby populations may face very unequal risks. This result was confirmed by the models focusing on the Lausanne urban area, suggesting that even within a city, with relatively similar population densities and socioeconomic conditions, local spatial variations in air pollution levels can lead to significant disparities in the spread and persistence of the virus. Furthermore, we also found that flatter epidemics (i.e., lower peakedness) were associated with higher total attack rates. This observation may indicate that areas with higher air pollution levels could be more susceptible to widespread and prolonged outbreaks, further emphasizing the importance of understanding and mitigating the effects of air pollution on public health.

The lagged population density, the location effects, and air pollutants had a major contribution in each period while other predictors only had a slight contribution. Overall, we only identified slight variations in the importance of determinants of cluster persistence across periods indicating stable determinants of SARS-CoV-2 diffusion despite new variant emergence.

Our univariate and multivariate XGBoost models revealed a relatively modest influence of the socioeconomic index on cluster persistence within the study area, indicating that socioeconomic factors may have limited predictive power for this specific aspect of SARS-CoV-2 diffusion dynamics. This outcome contrasts from previous research such as studies (7, 23, 24), which identified a significant relationship between socioeconomic status and COVID-19 outcomes such as case numbers and mortality rates. Notably, our analysis differs in focus: while Sun et al. (23) and Mena et al. (24) investigated case numbers and mortality rates at the local authority district and municipality level, our study examines the persistence of SARS-CoV-2 clustering, offering a perspective on the virus's spread.

To address the possibility that the SES index's low importance in our comprehensive model might stem from shared variance with other features, potentially overshadowing its effect, we conducted an additional analysis. A simpler multivariate XGBoost model, structured

similarly to those used for air pollutants, was fitted. The results from this streamlined model aligned with our initial findings, further substantiating the SES index's modest role in predicting cluster persistence. Importantly, our modeling approach prioritizes the practical significance of variables in predicting cluster persistence, rather than their statistical significance. This distinction is key to understanding the nuanced contribution of the socioeconomic index in our analysis. Complementing this, our sensitivity analysis with a Cox PH model, replicating the methodology from our previous work (7), showed a statistically significant association between the SES index and cluster persistence (HR = 0.49, $p < 0.005$), yet the model's predictive accuracy, as reflected by the C-index of 0.54, remained modest. Other factors such as public health interventions or population behavior may have a more substantial influence. Alternatively, the very low association could be due to limitations in the study design, measurement, or data quality. Further research is needed to confirm these findings and explore the underlying reasons, potentially using alternative measures of socioeconomic status and examining different geographic regions or time periods.

Strengths and limitations

While previous research has established a link between air pollution and respiratory diseases, including COVID-19, these studies have typically focused on broader regional impacts, often overlooking micro-level variations within small areas. Our findings contribute a novel perspective by revealing significant local spatial variations in the risks associated with air pollution, even within small regions. This granular insight is crucial as it underscores that within a region considered to have overall good air quality, there can still be pockets where air pollution reaches levels that significantly increased the persistence of the virus. These local disparities in air pollution exposure and related health risks highlight the limitations of averaging air quality measures over larger areas, which can mask such critical hotspots of air pollution and associated health risks. The policy implications of these findings suggest that current air quality standards and public health strategies when designed and implemented on a regional basis, may not adequately protect all citizens. Policymakers need to consider implementing finer-scale air quality monitoring systems capable of detecting and addressing these micro-level variations (64). Additionally, it is essential to targeted public health interventions that reflect this fine-scale information, ensuring that preventive measures and resources are specifically allocated according to localized risk levels.

Several methodological strengths of our study include the use of various measures of diffusion dynamics, a long study period (> 2 years), the inclusion of spatial effects, and air pollution data from two different sources (immission model and remote sensing estimation of tropospheric NO_2). Moreover, our study focuses on a relatively small geographical area with good epidemiological surveillance and presenting diverse sociodemographic and environmental conditions.

Additionally, the methodological approach employing advanced modeling techniques such as XGBoost models and SHapley Additive exPlanations (SHAP) values for model interpretation offered several advantages over traditional spatial methods like spatial lag models or GWR/MGWR (54). The XGBoost allowed us to capture complex non-linear and spatial effects, providing a more comprehensive understanding of the determinants of COVID-19 diffusion dynamics. Moreover, the use of SHAP values enabled a more interpretable and robust assessment of the importance of each feature in our models. SHAP values provided a unified measure of feature importance, considering both the magnitude and direction of the effect, as well as complex interactions between features. This approach made it possible to better understand the contribution of each variable in predicting cluster persistence.

However, our study also shows some limitations. Although we were able to include testing rates in the model, testing bias could still be a concern. The source and place of infection were unavailable, and we could only rely on the place of residence. Additionally, the tropospheric NO_2 estimation can be subject to biases, which may affect the accuracy of our results for this feature. Lastly, the generalizability of our findings might be limited due to the specific context of our study area.

Conclusion

Our study highlights the complex spatiotemporal dynamics of COVID-19 diffusion and its association with demographic, socioeconomic and more particularly environmental factors across 2 years of the pandemic. The use of advanced modeling techniques and a wide set of variables allowed us to gain a more detailed understanding of the determinants of COVID-19 spread. Air pollution appears to have played an important role in the COVID-19 pandemic in particular in relation to cluster persistence. Our study underscores thus the importance of implementing effective air quality management strategies to mitigate the potential adverse impacts of pollution on public health, particularly in the context of infectious diseases affecting the upper & lower respiratory tract, like COVID-19.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material; further inquiries can be directed to the corresponding author.

Ethics statement

This study was approved by the Commission cantonale d'éthique de la recherche sur l'être humain (CER-VD), Switzerland. Authorization no. 2020-01302. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because given the large number of individuals (± 200,000) involved and the retrospective nature of the study, procuring individual informed consent would pose a substantial challenge.

Author contributions

DR: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing, Project administration, Validation. AL: Conceptualization, Methodology, Validation, Writing – review & editing. YC: Conceptualization, Validation, Writing – review &

editing. DJ: Conceptualization, Validation, Writing – review & editing. SV: Conceptualization, Writing – review & editing. IG: Supervision, Validation, Writing – review & editing. SJ: Conceptualization, Supervision, Validation, Writing – review & editing. GG: Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Writing – review & editing.

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Conflict of interest

GG reports a research agreement with Becton-Dickinson and Company, and was co-director of JeuPRO, a start-up distributing the card games Mykrobs and Krobs, which are two games on microbes. DR reports a relationship with Becton Dickinson and Company that includes speaking and lecture fees and travel reimbursement. These relationships with industry do not represent a direct conflict of interest on the present epidemiological work on SARS-CoV-2.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1298177/full#supplementary-material

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Assessing the impact of the COVID-19 pandemic on the mental health of female entertainment workers in Cambodia: a group model building approach

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Background: The COVID-19 pandemic has intensified global mental health challenges, particularly for vulnerable groups like female entertainment workers (FEWs), a critical HIV-affected population in Cambodia. Already facing pre-existing inequalities, FEWs encountered heightened difficulties due to the pandemic's disruption of their livelihoods. Their susceptibility to mental health problems is exacerbated by poverty and the occupational stressors they regularly endure. This study aims to identify COVID-19-related factors adversely impacting the mental well-being of FEWs in Cambodia and explore potential interventions to mitigate these effects.

Methods: In December 2021, we conducted a two-day workshop in Phnom Penh using a group model-building approach with stakeholders from diverse backgrounds to gather collective insights. We employed the qualitative system dynamics method of causal loop diagram mapping to visualize the factors affecting FEWs' mental health. Based on participants' perceptions and experiences, we constructed a causal loop diagram to develop a comprehensive systems perspective.

Results: The workshop involved 27 stakeholders, including representatives from national institutions ($n = 3$), local NGOs ($n = 17$), an international NGO ($n = 1$), and the FEW community ($n = 6$). Our analysis identified 13 feedback loops highlighting key factors influencing the mental well-being of FEWs during the pandemic. These factors included the loss of family members, financial instability, fear of COVID-19 infection, the pressure of children's homeschooling due to school closures, and food insecurity. In response, stakeholders proposed a range of interventions, including alternative vocational training, increased awareness of mental health issues, access to mental health services, and programs targeting gender-based violence within FEW communities.

Conclusion: A collaborative, multi-sectoral approach is crucial to addressing the mental health challenges of FEWs in Cambodia. Prioritizing the establishment of accessible, affordable, and high-quality mental health services, alongside the implementation of targeted interventions, is essential to mitigate the negative

mental health impacts of the pandemic and enhance the overall well-being of FEWs.

KEYWORDS

COVID-19, mental health, female sex worker, group model building, low-and middle-income country, vulnerable population

Introduction

The COVID-19 outbreak severely impacted the world across physical, economic, psychological, and social dimensions. Declared a global pandemic by the World Health Organization (WHO) in March 2020, control measures to curb transmission have profoundly affected economies, communities, and individuals. COVID-19 has been called a "pandemic of inequality," disproportionately affecting the poor and vulnerable (1). Vulnerable populations, already facing economic, social, and health disparities, are at greater risk of poor health outcomes, particularly during crises (2). The interplay of social determinants and vulnerability increases the likelihood of developing mental health conditions (3), which in turn can perpetuate social exclusion and disadvantage. Poor mental health can, in turn, further beget social exclusion and disadvantage. Public safety measures implemented during emergencies often exacerbate the existing social and health inequalities these populations face. Many of these interventions led to economic hardship and lifestyle disruptions, fostering feelings of helplessness, uncertainty, and grief (3). Consequently, there has been growing attention to the impact of both the disease and the response policies on individuals' mental health.

In March 2022, the WHO reported a 25% increase in the global prevalence of depression and anxiety during the first year of the COVID-19 pandemic (4). Significant disruptions to service provision compounded this mental health burden, as healthcare resources were diverted to the pandemic response (5). Studies have shown that women are more likely to develop symptoms of mental disorders than men (4). However, data from lower- and middle-income countries (LMICs) and specific vulnerable groups remain limited.

Vulnerable populations often face significant structural barriers in accessing healthcare services, including vaccination, mental health care, and economic opportunities. Female entertainment workers (FEWs), a critical HIV-affected population in Cambodia, exemplify such vulnerabilities. The term "FEWs" emerged following the 2007–2008 global financial crisis, which led to widespread unemployment in Cambodia's garment industry and drove many young women into the entertainment and informal sex sectors. This shift was further influenced by the 2008 'Law on Suppression of Human Trafficking and Sexual Exploitation,' which banned brothel-based sex work (6). FEWs typically include young women employed at beer gardens, restaurants, karaoke bars, or massage parlors, as well as freelance sex workers who operate in public spaces, such as parks or streets, or on-call (7, 8). Our previous study found that 60.7% of FEWs engaged in transactional sex (8).

In 2019, the number of FEWs in Cambodia was estimated at around 70,000 (9). Most FEWs come from low-income rural families with limited education, including low health literacy (10), and many provide regular financial support for their families (11). They often face social stigma within their communities and have less social support compared to other women (12, 13). Studies have shown that FEWs experience similar stigmatization and criminalization as female sex workers (FSWs), regardless of whether they engage in transactional sex (14). FEWs, particularly those involved in sex work, are at higher risk for health issues, including mental health problems, due to occupational exposures such as unsafe sex practices, verbal abuse, forced alcohol consumption, and physical violence (15–17). Despite these known risk factors, mental health issues remain understudied in this population (18). Based on current evidence, data on the mental health of FSWs are likely the most relevant for understanding FEWs' mental health, with studies reporting up to 75% of FSWs experiencing mental health disorders (19–21). Moreover, social determinants such as low income, gender, limited education, inadequate housing, and unemployment, along with structural factors like gender inequality, harassment, arrests by law enforcement (22), lack of community support, unsafe work environments, and poor access to health and social services, further exacerbate their mental health vulnerabilities (23).

In 2015, a study reported that 43.2% of FEWs in Cambodia experienced high levels of psychological distress, 19.5% reported suicidal thoughts, and 7.3% had attempted suicide in the past 3 months due to past experiences and current working conditions (10). Those reporting low autonomy in their work environments—such as being forced to drink or having clients request unprotected sex—experienced higher levels of distress (10). The evidence indicates that FEWs, particularly those involved in sex work, face worse mental health outcomes than the general population, with a higher prevalence of suicidal behaviors, anxiety, psychological distress, depression, and post-traumatic stress disorders (24–26). Additionally, studies suggest that the poor mental health of FSWs can lead to risky behaviors, including unsafe sex practices and substance abuse (10). A 2020 systematic review and meta-analysis found that FSWs in LMICs had a high prevalence of mental health problems linked to behavioral and social factors they commonly experienced (22). Key risk factors for suicidal behavior and mental disorders—such as inadequate housing, HIV and other sexually transmitted infections (STIs), gender-based violence (GBV), drug and alcohol use, low education, financial stress, and discrimination and stigma (16, 17, 27, 28)—were reported at elevated levels among FSWs. Inconsistent condom use, drug use, HIV and other STIs, and GBV were also strongly associated with poor mental health in this vulnerable population (22).

The Cambodian government implemented stringent measures in early 2020 to curb the spread of COVID-19 (29, 30). These measures had far-reaching consequences, particularly for sectors like entertainment and informal sex work, severely disrupting the lives and livelihoods of many FEWs. Even before the pandemic, FEWs faced multiple challenges, including economic vulnerabilities and occupational stressors. The COVID-19 crisis exacerbated these pre-existing difficulties. Lockdowns, restrictions, and reduced economic activity disrupted their work, causing financial strain and deepening their vulnerability to various hardships. The cumulative

effect of these challenges had profound implications for the mental well-being of FEWs, as the heightened economic and social stressors during the pandemic likely contributed to increased psychological distress within this group.

The COVID-19 pandemic has exacerbated existing psychological issues globally, particularly among socially disadvantaged groups. A recent meta-analysis on the pandemic's impact on mental health found that unemployment, being under 40 years old, and female gender were associated with increased psychological distress (31). The analysis also highlighted that the pandemic uniquely intensified health risks and stressors for women (32). In addition to the external stressors created by the pandemic—such as economic instability and health risks—concerns about food security, housing, and fear of contracting COVID-19 while working without social protection are likely to worsen existing mental health conditions among FEWs (23). Moreover, the additional societal roles typically associated with women, such as childcare and education, may become more burdensome during the pandemic, further contributing to mental distress.

Cambodia's mental health services are already limited, even for the general population (33). Given the prevalent societal disparities in the country, FEWs are likely to face even more significant challenges in accessing mental health support. Therefore, this study aims to comprehensively identify the COVID-19-related factors adversely affecting the mental well-being of FEWs in Cambodia. It also seeks to pinpoint specific areas where targeted interventions can improve the mental health of this vulnerable group, addressing a critical healthcare concern within the context of the country's constrained mental health infrastructure.

Methods

Group model building approach

Data for this analysis were collected as part of a needs assessment during the COVID-19 pandemic within an ongoing intervention study to improve access to GBV services. We employed the GMB approach, a system dynamics model-building process. GMB is a participatory approach that engages a diverse group of stakeholders to develop a deeper understanding of complex issues by integrating and assimilating their mental models into a holistic system description (34). It emphasizes the complexity and dynamics of interactions between system components and provides a framework for interdisciplinary and transdisciplinary approaches to address complex problems (35). Additionally, GMB introduces social dynamics, which can influence model quality, stakeholder engagement, and the likelihood that recommendations will be accepted and implemented (36).

This study also utilized the qualitative system dynamics method of causal loop diagram (CLD) mapping to visualize the impact of the COVID-19 pandemic on the mental health of FEWs. A CLD is a visual tool that illustrates the interrelationships between variables within a system, consisting of variables or concepts, links (or arrows), and their polarities. The CLD captures the complex interrelationships identified through the GMB process to pinpoint the feedback mechanisms driving observed behaviors. Variables represent factors or concepts describing the system, while links (or arrows) indicate the direction of causal relationships, with plus (+) and minus (−) signs denoting the polarity of these relationships. Table 1 provides a detailed description of the notations used in the CLD.

Multiple stakeholders were engaged to incorporate diverse perspectives into a single conceptual model, capturing their understanding to achieve a comprehensive view of the relationship between the pandemic and mental health. The conceptual models developed with stakeholders were used to represent the dynamic relationships between outcomes of interest and underlying factors, providing a thorough insight into the complexity of the issue (37). This resultant model can enhance system-level understanding and inform the development of potential interventions.

Settings

A two-day GMB workshop was held in Phnom Penh from December 5th to 9th, 2021, in collaboration with the Khmer HIV/AIDS NGO Alliance (KHANA). We invited 28 stakeholders from various backgrounds (excluding the principal investigator and moderator) to participate in the GMB exercise, with 27 attending. KHANA identified and purposively sampled these stakeholders based on their personal and institutional experience with FEWs. Details of the stakeholder participants are provided in Supplementary Table S1.

The workshop was conducted in a hybrid format—via Zoom (38) and in person—due to difficulties reported by FEWs in attending via videoconferencing. The number of FEWs invited was reduced due to logistical constraints and COVID-19 restrictions on in-person gatherings. FEWs gathered at KHANA's headquarters with KHANA facilitators for their participation in the GMB session.

GMB exercise outline

Each day of the exercise featured a critical interactive activity. After presenting the agenda to stakeholders in the main room, participants were divided into three breakout rooms, each with a diverse mix of individuals. To ensure consistency across all groups, facilitators used a standardized script for each activity, adapted from Scriptopedia for the GMB approach. The facilitators were trained before the GMB exercise to maintain uniformity across breakout rooms. They encouraged active participation, ensuring that everyone had the opportunity to share their views. Participants elaborated on the factors they raised, while others were invited to provide additional input. The introduction and main discussions were conducted in English, with Khmer translation in the main room. During breakout sessions, discussions were held in Khmer, and facilitators translated the findings into English.

GMB exercise 1– variable elicitation

Day 1 involved a variable elicitation exercise to identify and discuss factors affecting the mental health of FEWs during the COVID-19 pandemic. The guiding question for stakeholders was: "*What factors, directly or indirectly, impact the mental health of FEWs due to the COVID-19 pandemic?*" Each group had 90 min for discussion. Facilitators sought clarifications to ensure a shared understanding and agreement among stakeholders before recording variables on a digital whiteboard. After the discussions, facilitators had 5 min to present and

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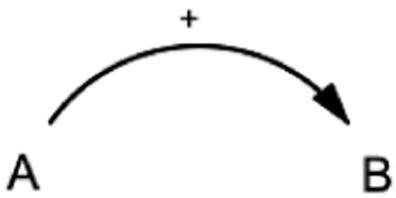
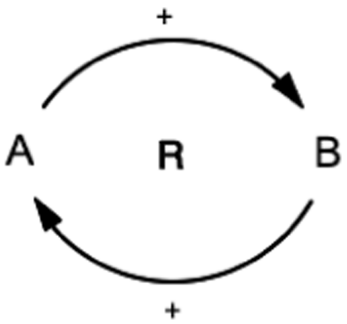
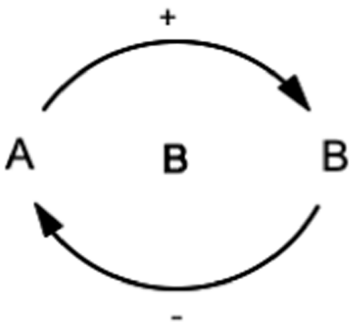
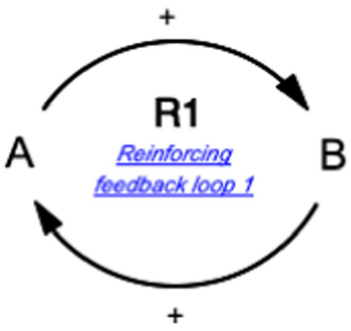
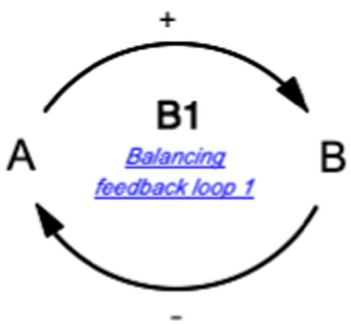
TABLE 1 Overview of notations for the causal loop diagram.

Symbol	Definitions and function in causal loop diagram
	"+" means an increase (or decrease) in variable A leads to an increase (or decrease) in variable B (i.e., a change in the same direction).
	"-" means an increase (or decrease) in variable A leads to a decrease (or increase) in variable B (i.e., a change in the opposite direction).
	"R" indicates a reinforcing feedback loop whereby an increase (or decrease) in "A" causes an increase (or decrease) in "B," which leads to a further increase (or decrease) in "A". A reinforcing feedback loop results in subsequent exponential change (either growth or decay).
	"B" indicates a balancing feedback loop whereby an increase (or decrease) in "A" causes an increase (or decrease) in "B," which leads then to a decrease (or increase) in "A." A balancing feedback loop results in changes toward equilibrium or moves the current state toward a desired state, seeking to stabilize a system.
	"R1" indicates reinforcing feedback loop number 1, and the feedback loop's name describes it. All reinforcing feedback loops are numbered for easy identification. **Supplementary Table S2** helps trace each loop's causal pathway by following the numbering variables in each loop.
	"B1" indicates balancing feedback loop number 1, and the feedback loop's name describes it. All balancing feedback loops are numbered for easy identification. Table B in the appendix helps trace each loop's causal pathway by following the numbering of variables in each loop.

summarize their variables on the main room's digital whiteboard. Variables elicited on Day 1 are depicted in Supplementary Figures S1a–c.

If any uncertainties remained, the modeler clarified the relationships between variables and mental health with stakeholders. By the end of Day 1, the modeler used notes from the variable elicitation exercise to construct a preliminary conceptual model using the bespoke software VenSim (39) based on their understanding of the discussions from Day 1.

GMB exercise 2– policy elicitation

On Day 2, a policy elicitation exercise was conducted to identify existing policies addressing the impact of the COVID-19 pandemic on FEWs' mental health and to discuss potential interventions. The guiding questions for stakeholders were: "*What interventions have been in place that improved the mental health of FEWs since the COVID-19 pandemic began? What additional interventions could enhance FEWs' mental health?*" Each group had 1 h for discussion, with facilitators recording the outcomes on a digital whiteboard. After the discussions, facilitators summarized the findings in a five-minute presentation. Policies identified on Day 2 are depicted in Supplementary Figures S2a–c.

The preliminary conceptual model was then presented to stakeholders to verify its accuracy and ensure it reflected their inputs. The modeler reviewed each causal loop with live translation provided by facilitators. Stakeholders' feedback during the review led to significant modifications to the model. The CLD was then refined and consolidated through iterative analyses using notes from the GMB sessions, aligning the variables and pathways with the underlying causal logic expressed by participants.

Ethics consideration

Participants received an invitation letter detailing the study's objectives and procedures. To protect their identities, personal information, such as ID numbers, addresses, and phone numbers, was not collected. Comprehensive briefings and written documentation explained the study's purposes, procedures, and potential risks. Informed consent was obtained through a form reviewed and signed by each participant, confirming their understanding and voluntary agreement to participate. Participants were informed that discussions in the main room would be recorded solely for refining the CLDs and were given the option to turn off their video cameras. Proxy names (e.g., P1, P2) were used to prevent linking identifiable information to sensitive experiences shared. Discussions focused on general factors and systemic aspects of mental health rather than personal anecdotes. The data collection team ensured confidentiality by not recording discussions within the breakout rooms. Participants were reimbursed for their travel costs and received a token of appreciation of USD 10 for participating in the GMB exercise.

Results

Participant characteristics

The workshop included 27 stakeholders: 17 (62.9%) were female, 17 (62.9%) were aged 21–40, 17 (62.9%) were from local NGOs, six (22.2%) were from FEW communities, three (11.1%) were from national institutions, and one (3.7%) was from an international NGO.

Causal map of the impact of the COVID-19 pandemic on FEWs' mental health

Based on the outcomes of the GMB exercise, we identified 13 feedback loops, including 11 reinforcing and two balancing loops. These feedback loops were categorized into three main themes: (1) COVID-19 and the fear of contracting COVID-19, (2) anxiety related to financial and economic situations, employment, and food security, and (3) lack of family support. Variables have been numbered for ease of reference and to facilitate tracing loops within the CLD.

COVID-19 pandemic and fear of contracting COVID-19

Figure 1 illustrates the feedback loops related to the impact of the COVID-19 pandemic and the fear of contracting COVID-19 on mental health. Table 2 provides the corresponding causal pathways. Reinforcing feedback loop R1 depicts the COVID-19 infection and recovery foundation. As the susceptible population grows, the number of exposed individuals increases, leading to more infections and, subsequently, more recoveries. Recovered individuals remain susceptible to reinfection, which enlarges the susceptible population. Balancing feedback loop B1 shows that as the susceptible population and the number of exposed and infected individuals rise, COVID-19-related deaths will increase, reducing the susceptible population. Additionally, as the number of exposed individuals rises, more people will adopt protective measures, decreasing community transmission and the subsequent risk of infection. Loop R1 is counteracted when a decrease in exposed individuals reduces transmission risk, forming balancing feedback loop B2.

Reinforcing feedback loop R3 indicates that as mental health stressors increase, FEWs' ability to work diminishes, leading to reduced income and heightened financial instability, which in turn exacerbates mental health stressors. Reinforcing feedback loop R4 shows that decreased income results in higher occupancy rates within rented spaces, heightening fears of contracting COVID-19 and increasing mental health stressors. This, in turn, reduces their ability to work, further decreasing their income. FEWs, often urban migrants who leave their families in rural areas for work, share their rented spaces with more people when facing reduced income or unemployment, increasing their risk of COVID-19 infection. The lack of social protection and reduced access to healthcare services heightens their fear of contracting COVID-19, adding to their stress. Additionally, stigma and discrimination against FEWs impede their access to COVID-19 vaccinations, further increasing their susceptibility to infection.

Reinforcing feedback loop R8 illustrates that as the number of infected individuals rises, COVID-19 restrictions tighten, reducing economic activities and subsequently affecting FEWs' employment and income. This situation exacerbates FEWs' financial instability and leads to increased violations of COVID-19 restrictions to earn money, heightening community transmission and the risk of infection. Reinforcing feedback loop R9 demonstrates how increased violations of COVID-19 restrictions by FEWs escalate their fears of contracting COVID-19, which

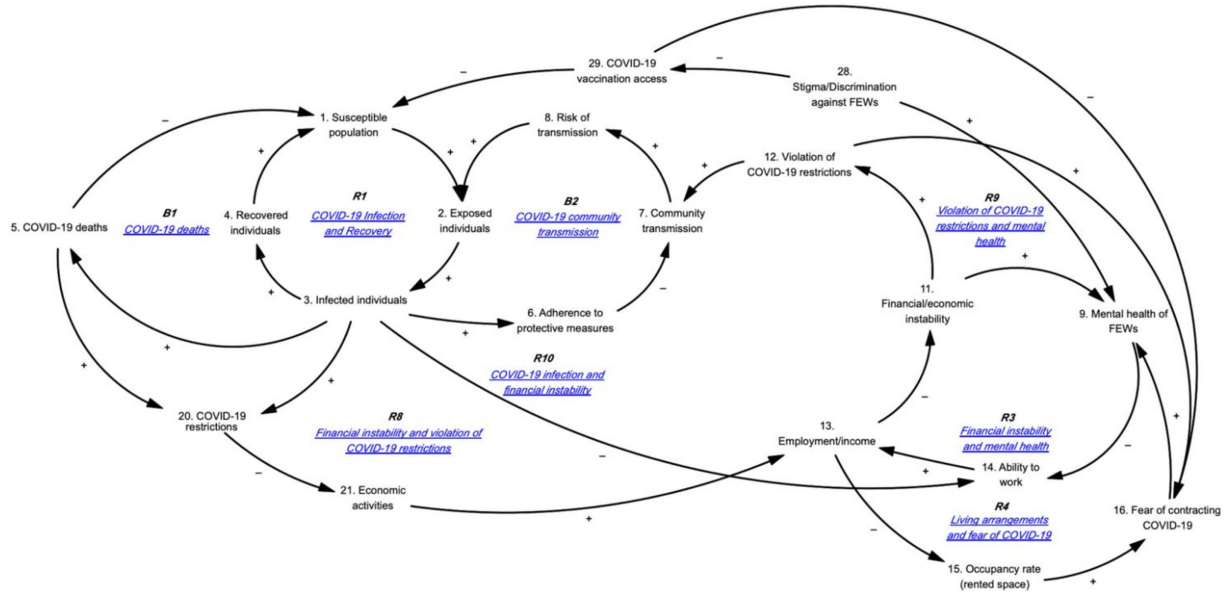


FIGURE 1
Impact of the COVID-19 pandemic and fear of contracting COVID-19 on mental health.

TABLE 2 Loop pathways of Figure 1.

Loop reference	Loop name	Loop pathway
R1	COVID-19 infection and recovery	1 ➔ 2 ➔ 3 ➔ 4 ➔ 1
R3	Financial instability and mental health	9 ➔ 14 ➔ 13 ➔ 11 ➔ 9
R4	Living arrangements and fear of COVID-19	13 ➔ 15 ➔ 16 ➔ 9 ➔ 14 ➔ 13
R8	Financial instability and violation of COVID-19 restrictions	3 ➔ 20 ➔ 21 ➔ 13 ➔ 11 ➔ 12 ➔ 7 ➔ 8 ➔ 2 ➔ 3
R9	Violation of COVID-19 restrictions and mental health	12 ➔ 16 ➔ 9 ➔ 14 ➔ 13 ➔ 11 ➔ 12
R10	COVID-19 infection and financial instability	3 ➔ 14 ➔ 13 ➔ 11 ➔ 12 ➔ 7 ➔ 8 ➔ 2 ➔ 3
B1	COVID-19 deaths	1 ➔ 2 ➔ 3 ➔ 5 ➔ 1
B2	COVID-19 community transmission	2 ➔ 3 ➔ 6 ➔ 7 ➔ 8 ➔ 2

heightens mental health stressors and reduces their ability to work. This decreased ability to work further diminishes income and financial stability, prompting more violations of COVID-19 restrictions. Participants reported that FEWs felt unsafe working without vaccination, leading to decreased revenue and increased stress.

Reinforcing feedback loop R10 reveals that as the number of infected individuals grows, FEWs' ability to work declines due to stricter COVID-19 restrictions, closure of entertainment venues, and fewer clients. The decrease in income heightens financial instability, leading to increased violations of COVID-19 restrictions, further amplifying community transmission and the number of exposed and infected individuals.

Anxiety toward financial/economic situation, employment, and food security

Figure 2 illustrates the feedback loops depicting how anxiety related to financial situations, employment/income, and food security—exacerbated by the COVID-19 pandemic—affects the mental health of FEWs. Table 3 presents the corresponding causal pathways. Reinforcing feedback loop R2 highlights that as mental health stressors increase for FEWs, alcohol consumption also rises, which leads to higher expenditures and greater economic instability, further intensifying mental health stressors. FEWs reported turning to alcohol in response to mental health challenges, creating a vicious cycle of financial instability and worsening mental health.

Reinforcing feedback loop R5 hypothesizes that decreased income leads to increased domestic conflict and GBV. FEWs reported that reduced income exacerbates domestic tensions, resulting in higher rates of GBV, including physical, psychological, and sexual violence. As the primary income earners for their families, FEWs experience intensified mental health stressors due to these conflicts, which, in turn, decrease their ability to work and earn income. Many FEWs endure GBV both at home and from clients, driven by their precarious economic situations and the desire to avoid further conflicts with their families.

Stakeholders noted that employment and income instability significantly influence FEWs' mental health, particularly during the pandemic. Some clients demanded rapid antigen tests without covering the cost, which added to FEWs' financial strain and distress.

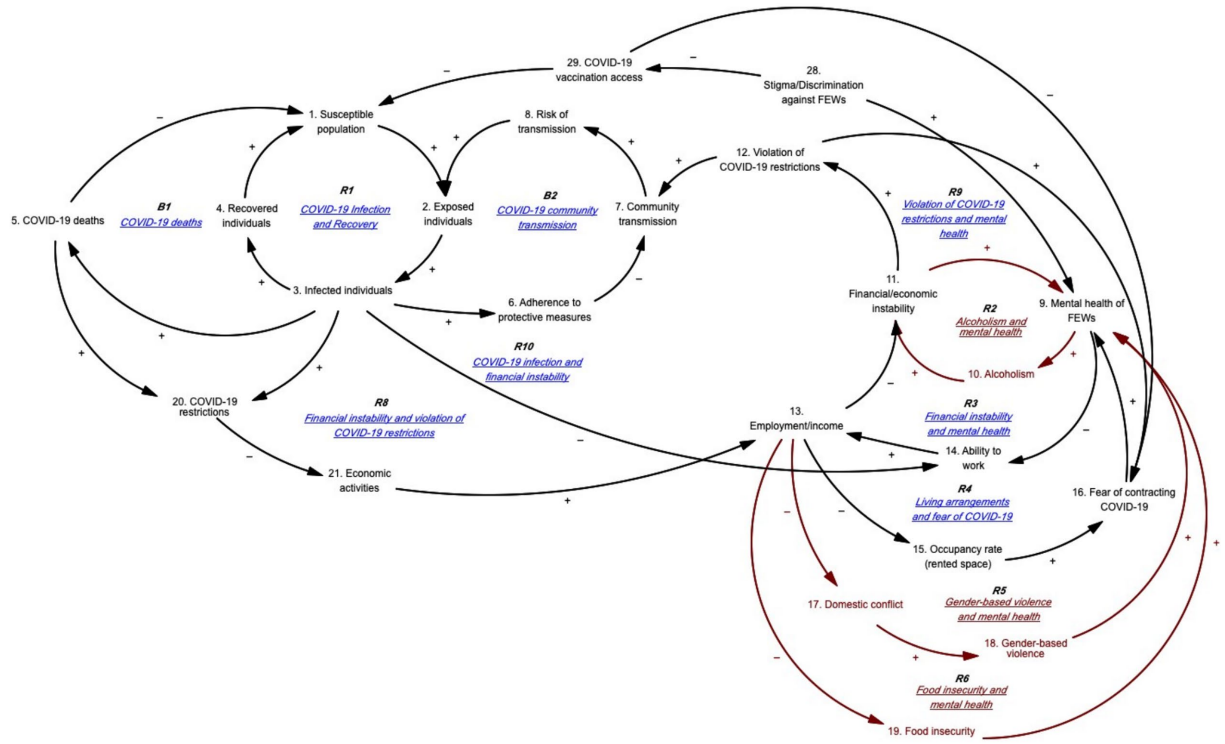


FIGURE 2
Anxiety toward financial/economic situation, employment, and food security.

TABLE 3 Loop pathways for Figure 2.

Loop reference	Loop name	Loop pathway
R2	Alcoholism and mental health	9 ➔ 10 ➔ 11 ➔ 9
R5	Gender-based violence and mental health	13 ➔ 17 ➔ 18 ➔ 9 ➔ 14 ➔ 13
R6	Food insecurity and mental health	13 ➔ 19 ➔ 9 ➔ 14 ➔ 13

With entertainment venues essentially closed, FEWs often violated COVID-19 restrictions to earn income despite the risk of contracting the virus. This led to harassment and arrests by law enforcement, further contributing to mental distress. The GMB exercise revealed that financial instability has a profound direct and indirect impact on FEWs' mental health, with severe effects on their primary source of income and limited opportunities for alternative employment due to their backgrounds and lack of vocational training.

Similarly, reinforcing feedback loop R6 demonstrates that decreased income contributes to increased food insecurity, which heightens mental health stressors and reduces work capacity and revenue. The COVID-19 pandemic severely affected food security and access in Cambodia, with market closures in Phnom Penh in April 2021 and transportation challenges exacerbating food shortages (40). Stakeholders reported that food insecurity became a critical issue for FEWs during the period.

Lack of support from and for family

Figure 3 illustrates the feedback loops showing how family-related issues contribute to FEWs' stressors. Table 4 details the corresponding pathways. Reinforcing feedback loop R7 indicates that as FEWs' income decreases, their access to technology and online platforms diminishes. This leads to higher dropout rates among their children and an increased need for home-schooling, which intensifies FEWs' mental health stressors. The time spent educating their children at home reduces their ability to work and earn income. During the COVID-19 pandemic, schools in Cambodia were closed for nearly two-thirds of the school year (250 days) in 2020 and 2021, resulting in significant learning loss (41). With the shift to online learning, FEWs faced difficulties providing their children with the necessary technology or access to online platforms due to financial constraints, leading to increased school dropout rates. Additionally, the responsibility for home-schooling often falls more heavily on women than men (42), exacerbating the stress for FEWs as they navigate the dual pressures of supporting their children's education and maintaining their work and income.

Reinforcing feedback loop R11 demonstrates that as COVID-19-related deaths rise, FEWs experience an increase in the loss of family members, leading to heightened bereavement and mental health stressors. Domestic travel restrictions exacerbated this situation, leaving FEWs feeling unsupported by their families. Those who lost family members to COVID-19 were often unable to return to see them in their final moments. This inability to grieve appropriately and say a final farewell intensified feelings of social isolation and worsened their mental health.

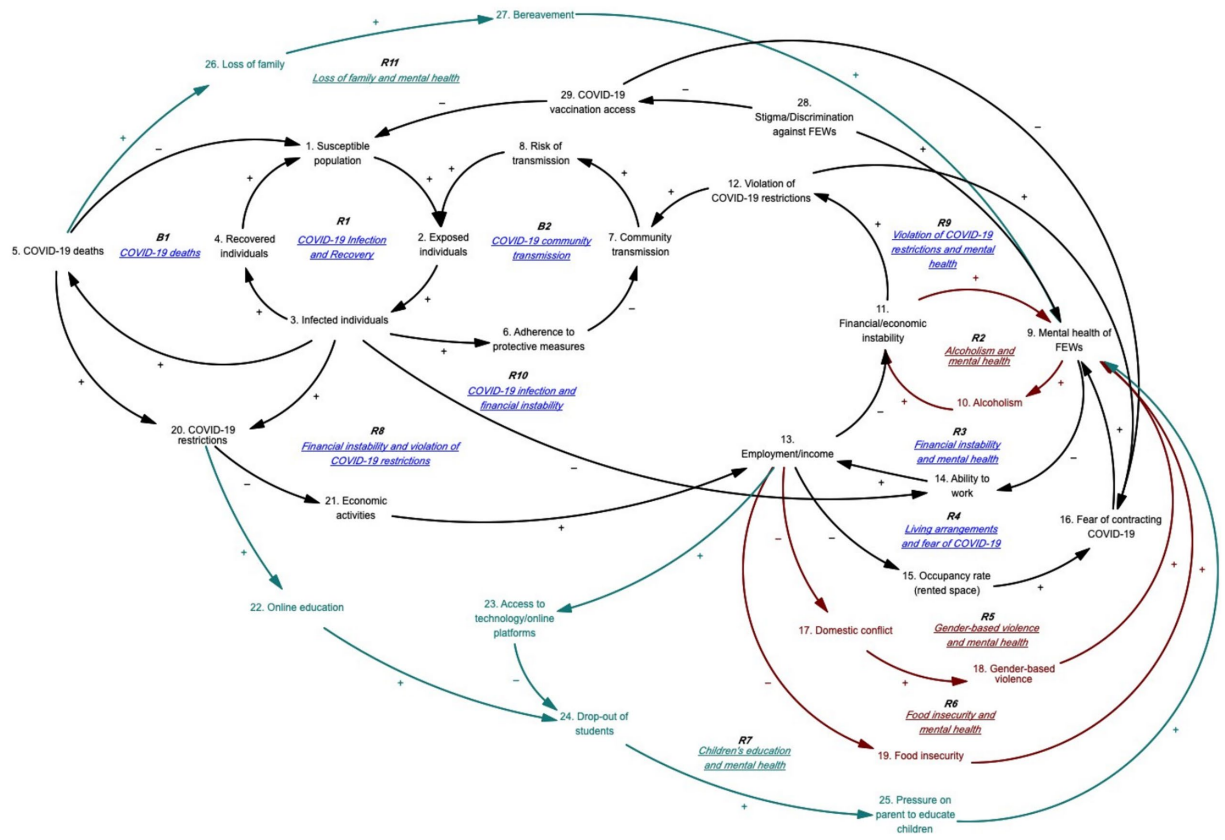


FIGURE 3
Lack of family support.

TABLE 4 Loop pathways for Figure 3.

Loop reference	Loop name	Loop pathway
R7	Children's education and mental health	13 ➔ 23 ➔ 24 ➔ 25 ➔ 9 ➔ 14 ➔ 13
R11	Loss of family and mental health	5 ➔ 26 ➔ 27 ➔ 9 ➔ 10 ➔ 11 ➔ 12 ➔ 7 ➔ 8 ➔ 2 ➔ 3 ➔ 5

Discussion

Our findings underscore how pre-existing issues faced by FEWs were exacerbated by the pandemic and reveal factors that may not have been previously identified in studies on the mental health of FEWs and FSWs. This study offers a comprehensive understanding of the diverse and interconnected factors impacting FEWs' mental health. Key stressors identified by stakeholders include financial instability, which was worsened by the pandemic, and anxiety related to COVID-19. Concerns about income and employment were linked to various other stressors that aggravated mental health issues. These findings align with past research highlighting stressors such as exposure to GBV, concerns about mental and physical health, and threats of arrest (14). They also reaffirm the close relationship between FEWs' mental health and their physical and occupational health (7), indicating that policies or programs addressing these areas are likely to impact all three aspects.

LMICs, including Cambodia, have faced significant challenges in developing mental healthcare systems due to factors such as insufficient resources and funding, lack of political will, and low prioritization of mental health compared to other public health issues (43). In Cambodia, the destruction of health infrastructure and services during the Khmer Rouge period has severely hindered the rebuilding of mental health services (44). The absence of mental health legislation (44) and poor policy implementation further delayed the development of the mental health system. Participants in our GMB exercise highlighted issues such as the lack of awareness and significant stigma associated with mental health diagnoses in Cambodia (43), which are consistent with previous research.

Stigma against FEWs and mental disorders exacerbates the difficulties FEWs encounter in accessing mental health services. Participants also pointed out issues related to service availability and quality, reflecting previous findings of gaps in mental healthcare (43). Marginalized populations like FEWs face even more significant challenges in accessing the already limited mental health services available to the general population. The pandemic has further reduced the availability of these services by redirecting healthcare resources, making it even less likely that

vulnerable communities will receive the mental health support they need. The high burden of mental health issues among FEWs highlights the urgent need for prevention and treatment services, as well as improvements in work environments to enhance mental health outcomes in the long term. This study provides a foundation for policymakers, mental healthcare providers, and organizations to explore mental healthcare provision and related factors to improve the overall mental health of FEWs.

Policy implications

We identified four main concerns stakeholders felt were most affected by the COVID-19 pandemic: employment/income, GBV, food insecurity, and access to mental health services. Consequently, four critical interventions were proposed to address these issues and improve the mental health of FEWs.

Employment and income were identified as critical leverage points impacting the mental health of FEWs. Stakeholders suggested that financial aid could significantly alleviate stressors related to instability in employment and income during emergencies. However, they also acknowledged that financial aid is a short-term solution and may be constrained by limited resources. To address this, they recommended that the government and development partners provide vocational training for FEWs, enabling them to pursue alternative employment opportunities. Such training could help FEWs transition out of the entertainment and informal sex work industries, potentially breaking intergenerational cycles of poverty and improving mental health and overall well-being.

Stakeholders highlighted a significant gap in mental health services, which was exacerbated by the COVID-19 pandemic. Even before the pandemic, FEWs faced considerable barriers to accessing care due to discrimination and stigmatization, impeding their ability to obtain necessary mental health support (45). Addressing these gaps requires fostering multi-sectoral collaboration between government and NGOs to drive meaningful improvements in mental health care. Government resources should be strategically allocated to expand general and mental health services, and community-based organizations should be utilized for outreach to identify at-risk FEWs and connect them with available support services. However, implementing these interventions involves several challenges, including limited funding, a shortage of trained mental health professionals, and community resistance due to stigma. Overcoming these barriers will necessitate substantial resources, including financial investment, training programs for healthcare providers, and public awareness campaigns to combat stigma. Additionally, integrating health screenings to assess and address occupational risk factors into existing health services will require careful coordination and resource allocation.

To address these challenges, a phased approach could be adopted, starting with pilot programs to test the feasibility of proposed interventions. These pilots should be accompanied by robust evaluation frameworks to assess their effectiveness and make necessary adjustments. Collaborating with international organizations and leveraging existing infrastructure will be crucial for mobilizing resources and expertise. By addressing these factors, it will be possible to implement the recommended interventions effectively and achieve meaningful improvements in mental health care for FEWs.

Lastly, GBV remains a pervasive issue among FEWs and requires urgent attention. The pandemic has intensified both global and Cambodian incidences of GBV (46). The Cambodian Centre for Human Rights reports that economic pressures heighten the risk of GBV, leading some FEWs into exploitative or abusive situations driven by financial necessity (47). This issue, identified in the GMB as a significant driver of mental health problems among FEWs, is further exacerbated by stigma and harassment from local authorities due to their job nature. Participants have emphasized the need for prompt responses from authorities when GBV incidents are reported to ensure the protection of FEWs. It is crucial to investigate existing processes within law enforcement agencies to identify challenges officers face in handling GBV reports. Once these barriers are identified, tailored interventions should be developed to enhance response times to GBV cases. Additionally, comprehensive training programs are needed to equip law enforcement officers with skills to engage with women in a gender-sensitive and trauma-informed manner.

To further substantiate our findings, future cost–benefit analyses should be conducted to quantitatively assess the financial implications of the strategies identified through the GMB. Collecting data on the costs of various public health interventions or policies and simulating their long-term health and economic impacts using the GMB framework will provide robust, quantitative evidence. This evidence will support more informed decision-making by clarifying the trade-offs between intervention strategies, highlighting potential barriers, and identifying necessary resources for effective implementation.

Strengths and limitations

The GMB exercise provided a platform for participants from diverse backgrounds, experiences, and age groups to openly discuss their perceptions of mental health issues—a topic that is often socially stigmatized within this vulnerable population in Cambodia. The findings are valuable for generating new hypotheses and pinpointing areas for intervention. The causal map illustrating the impact of the COVID-19 pandemic on FEWs' mental health offers stakeholders, policymakers, and organizations developing programs for FEWs a deeper understanding of the contextual factors affecting their mental well-being. This map also highlights leverage points for strengthening and improving mental health services for FEWs. Additionally, it serves as a visual tool that demonstrates the complex interrelationships among the various factors influencing FEWs' mental health.

This study has several limitations. Firstly, the FEWs involved may not fully represent the broader FEW populations in Cambodia, as they were primarily individuals already receiving aid through KHANA's community-based projects. Due to COVID-19 restrictions, we could include only a limited number of participants. Future research should aim to include a more extensive and diverse sample from various regions in Cambodia, including those not receiving aid, to improve representation and reduce bias. Secondly, despite efforts to de-identify participants, there may have been pressure to disclose sensitive

experiences in large groups, potentially leading to the under-reporting of certain variables. Additionally, the hybrid nature of the exercise, coupled with language barriers and time constraints, may have resulted in the loss of specific perspectives during translation, particularly in model conceptualization.

Lastly, while GMB enhances stakeholder engagement and understanding, it has notable limitations. The process is time-intensive, requiring significant effort to organize, facilitate, and synthesize group input, which can delay decision-making in urgent situations. Effective facilitation is crucial; without it, group dynamics may negatively impact model outcomes. However, facilitator training can help mitigate this issue. The collaborative nature of GMB can sometimes lead to groupthink, where dominant voices skew the model. Trained facilitators work to ensure balanced participation. Aligning diverse stakeholders with varying priorities can also be challenging, but focusing on shared outcomes and revising the model through iterations helps achieve consensus.

Translation and interpretation challenges were carefully managed while conceptualizing the CLDs to ensure the accuracy and relevance of the data. Experienced translators and interpreters, well-versed in both the technical language of the study and the local context, were employed to minimize misinterpretations and capture the nuances of the discussions accurately. Facilitators were also trained to address potential language barriers during sessions, and multiple rounds of review were conducted to verify the accuracy of the translated data. Possible impacts of translation and interpretation issues include the risk of miscommunication, which could lead to inaccurate representations of stakeholder inputs and introduce biases into the CLDs.

To mitigate these risks, we implemented several measures: regular feedback loops between translators and facilitators, iterative verification of translated content with participants, and cross-checking key concepts for consistency across languages. These steps aimed to maintain data integrity and ensure that the final CLDs accurately reflected participants' inputs. In the analyses, we addressed ambiguities by incorporating iterative validation processes and seeking expert input. Stakeholders and experts reviewed and provided feedback on the CLDs, helping to clarify and refine the causal relationships. Additionally, sensitivity analyses were conducted to explore how changes in causal assumptions might affect overall model outcomes. These measures were designed to ensure that the CLDs accurately represented the complex dynamics of the system while acknowledging and mitigating potential ambiguities.

Conclusion

This study identified several key factors affecting the mental health of FEWs, an HIV key population in Cambodia, during the COVID-19 pandemic. These factors include bereavement, financial instability, fear of contracting COVID-19, child homeschooling responsibilities, and food insecurity. The study highlights potential interventions to address these challenges, such as vocational training, mental health awareness programs, and efforts to combat GBV within this vulnerable population. The study underscores the importance of recognizing the complex interplay of these factors and their impact on FEWs' mental health, providing valuable insights for future interventions and policies. It emphasizes the global importance of prioritizing mental health, given its connections to physical health, and calls for improved access to mental health services for FEWs, including telehealth options, while acknowledging existing gaps in service coverage and quality. Additionally, this study suggests the need for formal evaluations of proposed interventions before their implementation. Future quantitative research is essential to validate and complement these findings, providing more detailed and generalizable data on the factors affecting FEWs' mental health and helping to refine the proposed interventions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the National Ethics Committee for Health Research of the Ministry of Health in Cambodia (NECHR, reference No. 169 NECHR, renewal reference No. 002 NECHR). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CC: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft. JA: Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – review & editing. ST: Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing. SO: Investigation, Methodology, Project administration, Validation, Visualization, Writing – review & editing. MU: Investigation, Project administration, Supervision, Validation, Visualization, Writing – review & editing. SY: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1336785/full#supplementary-material

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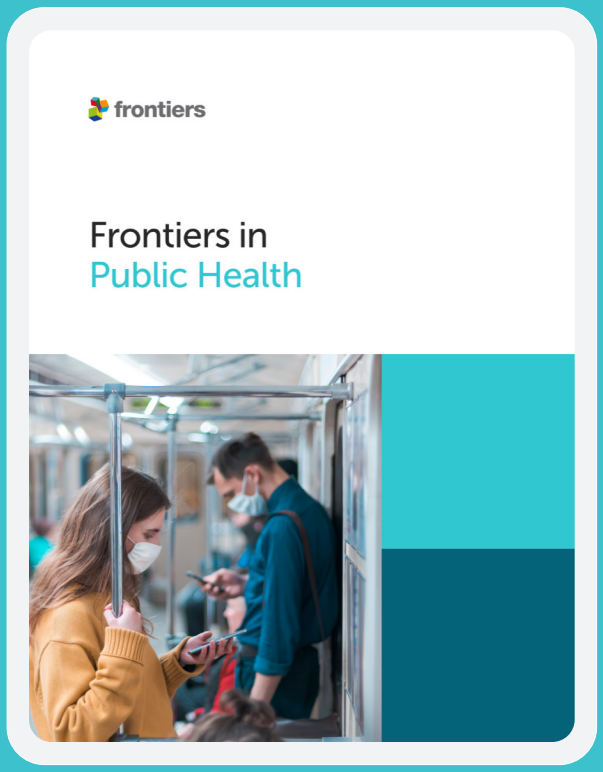

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