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Public health, public health education, and their future prospects

Edited by
Xuelei Ma, Hubing Shi and Yihui Du

Coordinated by
Wenhao Cai

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Public health, public health education, and their future prospects

Topic editors
Xuelei Ma — Sichuan University, China
Hubing Shi — Sichuan University, China
Yihui Du — University Medical Center Groningen, Netherlands

Topic Coordinator
Wenhao Cai — Sichuan University, China

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EDITED AND REVIEWED BY
Christiane Stock,
Charité—Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Germany

*CORRESPONDENCE
Yihui Du
✉ yihuidu325@gmail.com
Hubing Shi
✉ shihb@scu.edu.cn
Xuelei Ma
✉ drmaxuelei@gmail.com

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Editorial: Public health, public health education, and their future prospects

Yusha Wang[1,2], Yihui Du[3]*, Hubing Shi[1]* and Xuelei Ma[1]*

[1]Department of Biotherapy, Cancer Center and State Key Laboratory of Biotherapy, West China Hospital, Sichuan University, Chengdu, Sichuan, China, [2]Lung Cancer Center, West China Hospital, Sichuan University, Chengdu, Sichuan, China, [3]Department of Epidemiology, University Medical Center Groningen, University of Groningen, Groningen, Netherlands

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Editorial on the Research Topic
Public health, public health education, and their future prospects

Based on the need of healthcare worker with self-learning potential and public health skill, the medical education mode has been constantly explored and reformed. Novel teaching modes such as lecture-based learning (LBL), game-based learning (GBL), and team-based learning (TBL), empower students to learn and grow better compared with conventional instructor-led mode (1–3). Due to the rising awareness of public health, medical teaching mode has been momentous facilitated in the epidemic era. Therefore, this Research Topic recruited studies including multiple approaches for education, impact of COVID-19 epidemic on the public health, and researches on other diseases which serve as a public burden.

In recent years, with the gradual enrichment of non-traditional education strategies, education models have been widely discussed and applied. In this Research Topic, some articles explored different novel education modes. For instance, Zhang et al. systematically reviewed randomized controlled trials about TBL and LBL in nursing education, and found that TBL was generally more effective than LBL in improving academic achievement and overall competence. Xu et al. reviewed recent researches on the GBL in medical education, and found that serious games and gamification could improve the participation of students in class, and stimulate the motivation to learn. In Saudi Arabian, Alrabiah et al. investigated pharmacy students' perceptions of arithmetic and their mathematical abilities, thus found that integrating mathematics focused instruction into pharmacy curricula could improve its applicability in healthcare. Moreover, blended learning which refers to the combination of face-to-face teaching and online learning, has become increasingly popular. Study of Wang C. et al. showed that the inclusion of online learning tools in physical education curricula had a significant benefit, whereas instructional design, technological literacy, and self-regulation strategies are needed.

Owing to the COVID-19 epidemic, the application of online distance learning mode is widespread around the world. Qiu et al. studied the effect of online distance and on-site teaching modes. The general teaching effect was proven to be comparable, while domestic on-site teaching mode may provide better in-class teaching effects. With the modern technology rapid development and the educational mode iteration, Wang X. et al. explored the ability of artificial intelligence (AI) to process massive data,

the value to provide personalized and efficient educational solution, and the potential to revolutionize public health education. Additionally, Qu et al. found a correlation between procrastination and burnout among medical students during the epidemic in China, with both positively related to negative academic sentiment. Consequently, the role of general academic emotions (GAEs) in procrastination and burnout was emphasized. Notably, during the online teaching mode rising application worldwide, digital sobriety strategy is believed to reduce carbon emissions and enhance the sustainable development of digital technology. Gandhi et al. found that the carbon footprint of continuing medical education (CME) was significantly lower under the virtual digital sobering strategy in India, but the satisfaction of virtual learning was low. The aforementioned articles explored different teaching methods, suggesting that there is hope for reforming medical education modes and applying them to practice.

Health literacy plays an essential role in this era as the public becomes more reliant on digital resources. Accordingly, there are articles in this Research Topic that focus on health literacy and attempt to establish health literacy assessment tool, as well as explore the quality of evidence in public health research. Lau et al. assessed the COVID-19 specific health literacy of teachers in Hong Kong. Results showed that about half of teachers possessed adequate health literacy, while a large proportion of teachers still show poor understanding of health. It is highlighted that interventions should be carried out to improve health literacy of teachers. A questionnaire for the assessment of health information literacy level developed by Yu et al., and the results demonstrated that it was a valuable tool with good reliability and validity. Furthermore, Xun et al. systematically explored the differences in the sources of evidence, the types of primary studies, and the tools evaluating the quality of studies in public health systematic reviews (SRs). The results indicated that SRs should evaluate the quality of individual studies and evidence for these results.

Not only that, this Research Topic included some articles on other public health issues. Situational awareness (SA) is the basis of decision-making process and an important cognitive construct for positive safety outcomes of patients. Ghaderi et al. have shown that the SA of ICU nurses includes perceiving the cues of patient and environment, understanding the current situation by analyzing cues, and predicting the state of patients. The risk of disability connected with health-related factors and chronic diseases is studied in a wide range. Kim et al. found that factors such as smoking, alcohol consumption, and physical activity were associated with new disabilities, while physical activity and people with higher education and income levels were at low risk. These results can be a vital foundation for health care policies and strategies to prevent and reduce disability. The incidence of AIDS is substantially increasing year by year, and effective prevention is necessary. Bahikire et al. investigated the low use rate of non-occupational post-exposure prophylaxis (nPEP) to prevent HIV acquisition among fishers in Uganda, was mainly by virtue of lacking nPEP awareness. Thereby, increased community sensitization and improved HIV prevention education, are important. Walking is recognized and considered to be the most convenient form of physical activity (PA). Safi et al. aimed to promote PA for university employees by recommending daily steps and providing incentives on a team basis. This rewarding intervention had a positive impact on the personal and work outcomes.

As for the management of diabetes, Pi et al. found significant gaps in knowledge and management practices among primary care providers (PCPs) in the Central China region, highlighting the need of structured programs to enhance the prediabetes-related knowledge and practice of PCPs. It is important to formulate intervention strategies about physical activity in coronary heart disease (CHD) patients. Alsaleh and Baniyasin discussed the low level of physical activity in CHD patients in Jordan, and identified the barriers incorporating psychological, environmental, and health-related factors. Likewise, Guo Z. et al. investigated that the majority in South China had a moderate perception of cardiovascular disease risk, whereas individuals with high blood pressure, alcohol consumption, and better subjective health status underestimate the risk. And older age, higher income, diabetes, and better health are greatly associated with a higher cardiovascular disease risk. Metabolic syndrome (MetS) is known as a constellation of metabolic disorders comprising dyslipidemia, increased arterial blood pressure, and impaired fasting glycemia. Guo L. et al. found that more than 11 h per day for sedentary time was correlated well with an increased risk of MetS among Tibetans in China. These findings emphasized the importance of health education and reducing sedentary time.

In conclusion, articles in this Research Topic provide valuable insights and guidance for medical education modes and public health issues in the epidemic era. Among these articles, teaching modes such as TBL, LBL, and GBL contribute to learn basic medical knowledge efficiently for medical students. Online distance and AI assisted teaching modes promote to complete GME and obtain cutting-edge medical information for medical staff. Moreover, articles that addressed the causes, prevention, and management of other public health problems such as AIDS, diabetes, and CHD, are able to reduce the public health burden.

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YW: Writing – original draft. YD: Writing – review & editing. HS: Writing – review & editing. XM: Writing – review & editing.

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EDITED BY
Yihui Du,
University Medical Center Groningen, Netherlands

REVIEWED BY
Katalin Dr. Papp,
University of Debrecen, Hungary
Kirk Hamilton,
Texas AM University, College Station, United States

*CORRESPONDENCE
Roghayeh Esmaeili
r.esmaieli@sbmu.ac.ir

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Situation awareness in intensive care unit nurses: A qualitative directed content analysis

Chiman Ghaderi [1], Roghayeh Esmaeili [2*] and Abbas Ebadi [3,4]

[1]Student Research Committee, School of Nursing and Midwifery, Shahid Beheshti University of Medical Sciences, Tehran, Iran, [2]Department of Medical-Surgical, School of Nursing and Midwifery, Shahid Beheshti University of Medical Sciences, Tehran, Iran, [3]Behavioral Sciences Research Center, Life Style Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran, [4]Nursing Faculty, Baqiyatallah University of Medical Sciences, Tehran, Iran

Background: Situation awareness (SA) is an essential cognitive construct to create positive patient safety outcomes. SA of the nurses in the intensive care unit (ICU), where conditions may change rapidly, is particularly important. The present study aimed to explain the perception and experience of SA in ICU nurses based on Endsley's SA model.

Materials and methods: This qualitative directed content analysis was conducted on nurses in six hospitals in Tehran, Iran, from December 2020 to July 2021. Twenty-seven ICU nurses were selected using purposive sampling. Data were collected by semi-structured interviews and field observations. The data were analyzed based on the Elo and Kyngas method modified by Assarroudi et al. COREQ checklist was used to report the research.

Results: The concept of SA in ICU nurses, based on Endsley's model, includes perception of patients' clinical cues, perception of the human environment, perception of the physical environment, and perception of the organizational environment as generic categories of the perception of the elements in the environment. SA in ICU nurses also includes the main categories of comprehension the current situation through a sense of salience and interpretation of cues and projection the future situation through the prediction of patient status into the near future and environmental foresight.

Conclusion: Findings have further developed the concept of SA in ICU nurses based on Endsley's SA model. The insights and knowledge gained from this study can be useful for future practice, education, and research on SA among ICU nurses.

KEYWORDS

Situation awareness, intensive care unit nurses, intensive care unit, directed content analysis, Endsley's model

Introduction

Endsley (1), an aviation and military theorist, defined Situation awareness (SA) as "the perception of the elements in the environment in a volume of time and space, the comprehension of their meaning, and the projection of their status into the near future" (1). In the mid-1990s, the value of this concept was first introduced into anesthesiology with a direct emphasis on patient safety in health care, and its application then spread to other health professions, including nursing (2–4).

SA is an essential cognitive construct to create positive outcomes for patient safety (5). SA is the foundation of the decision-making process in the clinical setting and is a key feature in enhancing accountability and clinical management and reducing medical errors (6, 7). This is especially the case in ICUs due to the wide variety of hospitalized patients, the use of special treatment methods, the need for immediate and high-risk decisions, and the use of specific medical and pharmaceutical tools (8–10). The ability to interpret key information and make predictions for a dynamic situation is a hallmark of the higher levels of SA.

Emerging evidence indicates that inadequate SA may be responsible for half of the adverse events in hospital settings due to constant failure to recognize and respond to signs of patient deterioration in a timely manner (11, 12). As the largest group of care providers who perform important tasks such as patient assessment and 24-h care, nurses work at the forefront of the health care system, where they can identify vulnerabilities in the system and maintain patient safety (13, 14). The presence of SA in the nurse is a prerequisite that should be clearly identified, defined, and operationalized for safe care (2, 6, 14). Compared to other disciplines, this concept is relatively new in nursing and is not yet well explored (6). In their study, Walshe et al. (15) emphasized that more studies connected with the concept of SA have to be conducted in nursing (15).

Purpose

Lack of clarity in this key concept can lead to its devaluation and incorrect use in the patient care process (2). There is a clear need to understand nurses' perspectives and experiences using a qualitative approach based on a naturalistic paradigm to further identify and clarify the concept of nurses' SA in the ICU. Therefore, this study aimed to explain the perception and experience of SA in ICU nurses.

Theoretical framework

In Endsley's theory, SA has three levels: perception, comprehension, and projection (1, 16). Level 1 is the perception of the elements in the environment and will be the basis for levels two and three. Cues are perceived by one or more of the five senses. At level 2, the person begins to distinguish patterns, recognize the connection between cues and goals, and create a unified picture of the situation. In level 3, based on the understanding achieved in level 2, the person begins to predict; this level is the highest level of SA (1, 16). We chose this theory because it provides a universal model and the most widely accepted definition of situational awareness. Endsley's model is the most commonly used in health care. More importantly, it emphasizes the possibility of abstraction at all three levels, which is consistent with the objectives of this study (15).

Method

This study was conducted using the directed content analysis method. Directed content analysis is used to validate and develop the theories related to a studied phenomenon (17). The Consolidated criteria for reporting qualitative research (COREQ) checklist was utilized in this study to provide an exhaustive report (Supplementary material 1) (18).

Participants

Twenty-seven nurses working in ICUs of six teaching hospitals in Tehran, Iran, with maximum diversity in terms of age, gender, work experience, and level of education, were included in the study. The participants were selected based on purposive sampling, a suitable method for qualitative research (19). Nurses employed in different work shifts with at least a bachelor's degree were included in the study. Nursing managers, supervisors, and ward managers who were not directly involved in patient care were not included. The ICU sizes in this study ranged from 5 to 26 beds.

According to Sandelowski's (20) suggestion, the sample size should be more qualitative than quantitative, and its size should be determined by data saturation (20). We continued data collection until saturation was achieved. In general, saturation refers to a situation in which further information is not obtained by continuing to collect data (21). In this study, data saturation was obtained after 22 interviews, but another five interviews were conducted to ensure no new information is added to the study.

Data collection

Data collection was done from December 2020 to July 2021 through one-on-one in-depth semi-structured interviews with open-ended questions. Interviews were conducted with a conversational and emphatic approach (19). All interviews were conducted by the project PhD student who had received

TABLE 1 Interview guide.

Perception	When you hand over your patient at the beginning of the shift, what assessments and evaluations do you do? How about in the ward? What do you pay attention to? What do you monitor in your patient during the shift?
Comprehension	What is the purpose of this assessment and monitoring? How do you diagnose a patient's condition based on their cues and symptoms?
Projection	Can the patient's problems be predicted in the ICU? Can you explain how? When you take over the shift, have you ever thought, "what a shift it is going to be today!" Can you talk a little bit about this?
Closing questions	In your opinion, what does it mean when they say an ICU nurse should know what is going on around them during care provision? Before we end the interview, is there anything I missed that you would like to add?

complete training on conducting qualitative studies and interviews using the interview guide (Table 1). During the interviews, exploratory questions, such as "What do you mean?" or "Please explain more," were used to increase the interviewer's understanding of the participants' experiences.

At the end of each interview, the participant was asked, "In your opinion, what does it mean when they say an ICU nurse should know what is going on around them during care provision?" to allow them to think about their perceptions, their efforts to understand their situation and their role as an ICU nurse.

After the end of each interview, the participant's personal information, including age, gender, work experience, place of work, level of education, and position in the ward, were entered into an information form. Interviews ranged from 18 to 87 min (971 min in total).

This study used unstructured observation alongside the interviews to collect data. The researcher referred to the ICUs in 15 day and night shifts (at the beginning, during, and end of shifts), each for 2–3 h (40 h in total), and observed the daily activities of the nurses, their care provision, interactions of nurses with each other, their patients, and their colleagues. Close observation enables the researcher to closely follow the everyday experiences of the nurses and validate them (19). The environmental conditions of the ward and field observations were recorded in all visits and included in the data analysis.

Data analysis

The transcripts of the interviews were analyzed according to the eight steps presented by Assarroudi et al. (22) for organizing the data (22). Data analysis began at the same time as data collection. The analysis unit in this study was the transcript of the interviews and the interviewer's observations in the field.

The main steps of the directed qualitative content analysis included reading the text of the interviews several times to immerse yourself in the data, entering the text of the interviews into MAXQDA software version 10 to manage the data, developing a formative categorization matrix to place the codes into predetermined categories based on the three levels of Endsley's (1) model, extracting semantic units as sentences or paragraphs from interview texts and specifying the initial codes, placing the codes based on common characteristics of subcategories, placing the subcategories into generic categories of the coding matrix, creating new generic categories for those subcategories that did not fit into any of the generic categories, constantly examining the relationship between the new generic categories and the main categories, selecting participants' contributory quotes for each extracted feature, and providing an operational definition for SA based on the combination of participants' perceptions and the extracted latent content.

Ethical considerations

This qualitative study is a part of the PhD dissertation in nursing, approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences with the code IR.SBMU.PHARMACY.REC.1398.032. Informed consent to participate in the study was obtained from individuals. The participants determined the time and place of the interview and were asked for permission for their voices to be recorded.

Trustworthiness

Speziale et al. (19) criteria, including credibility, dependability, transferability, and confirmability to ensure trustworthiness, were considered. The research team reviewed the interviews after being coded to achieve peer review. External review was done by two nursing assistants outside the research team, and participant reviews were also done randomly by three participants to confirm the accuracy of the results. Purposive sampling with maximum diversity helps data transferability. In addition to the complete report of all the steps performed and the clear description of the analysis process, participants' quotations were also recorded to indicate that the findings are relevant to the data.

Results

Twenty-seven nurses working in ICUs participated in this study. Participants included 11 men and 16 women aged 26–50 years and work experience of 7 months to 26 years from different ICUs (Table 2).

In the analysis of interviews, 1,128 primary codes were extracted. After merging similar codes, 71 primary codes with

TABLE 2 Characteristics of participants.

Participants	Age (year)	Gender	Education	Professional title	Type of ICU	Working experience in ICU (year)
N1	34	Female	PhD	Supervisor	General	4
N2	42	Female	Bachelor	Supervisor	Neurosurgery	3
N3	48	Female	Master	Supervisor	Respiratory	6
N4	28	Female	Bachelor	RN	General	5
N5	45	Female	Bachelor	RN	Respiratory	8
N6	29	Male	Bachelor	RN	General	1
N7	43	Female	Master	Supervisor	General	10
N8	37	Female	Master	RN	General	6
N9	26	Female	Bachelor	RN	General	2
N10	33	Female	PhD	RN	Respiratory	5
N11	50	Male	Bachelor	RN	Toxicology	20
N12	35	Male	Bachelor	Supervisor	Neuro surgical	10
N13	49	Female	Bachelor	RN	Toxicology	26
N14	33	Male	Bachelor	RN	Cardiac surgery	6
N15	33	Female	Master	RN	General	7 (Month)
N16	26	Female	Bachelor	RN	General	3
N17	43	Male	Bachelor	RN	Toxicology	10
N18	38	Male	PhD	RN	Cardiac surgery	7
N19	38	Male	Bachelor	Supervisor	Cardiac surgery	7
N20	31	Male	Master	Supervisor	General	5
N21	28	Male	Bachelor	RN	Toxicology	2
N22	47	Female	Bachelor	RN	Toxicology	8
N23	45	Male	Bachelor	RN	Toxicology	23
N24	37	Female	Bachelor	RN	Covid-19	10
N25	35	Female	Bachelor	RN	Cardiac surgery	10
N26	37	Female	PhD	RN	General	5
N27	32	Male	Master	RN	General	3

a frequency of 780 were obtained. After their integration, finally, 19 subcategories were obtained, which were placed in 8 generic categories and the three main categories of "the perception of the elements in the environment," "comprehension of the current situation," and "projection of future status," according to Endsley's theory of situational awareness, which will be explained separately. Table 3 shows the main categories, generic categories, and subclasses.

Main category 1: The perception of the elements in the environment: Building blocks of nurse's situational awareness

The most basic and essential activity to know what is going on around us is to get information about that situation. The patient is the main component of the clinical situation. The ICU nurses pointed out that by correctly identifying the patient, reviewing the patient's document, communicating with the patient's relatives, and accurately assessing the patient, they perform the initial assessment of the patient at the beginning of the shift and collect fixed and basic patient information. You only need to collect fixed information once to be retrieved later whenever necessary.

> *"The patients stay here for a long time, more than just a few days; once you read the file, you will know everything. What was their complaint? What is their history? It is very important to have a first impression of the patient."* N5

Information such as vital signs and cues of changes in a patient's condition is dynamic information. For dynamic information, you need to be constantly monitoring the patient. Nurses stated that they were continuously evaluating the patient by being present at the patient's bedside, using their senses and monitoring devices, and communicating with the patient or other members of the treatment team.

TABLE 3 Main categories, generic categories, and subcategories of SA in ICU nurses.

Main categories	Generic categories	Subcategories
The perception of the elements in the environment	The perception of the patient's clinical cues	Initial patient assessment
		Continuous patient assessment
		Comprehensive attention to the dimensions of patient health
		Attention to patient handover
	The perception of the human environment	Simultaneous attention to patients
		Dynamic interaction with the team
	The perception of the physical environment	Awareness of patient and ward equipment
		Attention to the environmental conditions of the ward.
	The perception of the organizational environment	Awareness of existing care protocols and measures
		Awareness of the duties and roles of the nurse
Comprehension of the current situation	Sense of salience	Ensuring the accuracy of the cues
		Recognizing the cues
	Analysis and interpretation of cues	Critical review of symptoms and cues
		Problem diagnosis
Projection the future situation	Prediction of patients' status in the near future	Projection of the patient's situation
		Projection for action
		Projection of possible complications
	Environmental foresight	Expecting a sudden change of circumstances contrary to the expected conditions.
		Predicting the shift conditions when entering the ward

> *"The best way is for the nurse to constantly be beside the patient and do everything there because this way they will definitely notice the smallest issue."* N4

> *"Patient's vital signs should be monitored constantly. Although every patient here is being monitored by the systems, we should be attentive that the pulse oximetry is connected and the chest leads are correctly placed." N5*

> *"The patients themselves tell us if they are feeling better or not; but the thing is, not every patient in the ICU is conscious although we sometimes do have conscious patients." N7*

In addition to these evaluations, ICU nurses emphasized comprehensive attention to health dimensions by having a holistic view, examining physiological needs, communicating with the patient, and paying attention to the psycho-social dimension of patients in the ICU and during patient handover.

> *"When I notice that the patient is anxious, I'll try to talk to them and see if I can make them feel better by talking. Anyway, some people are very dependent on their families, so the patient's companion can come to their side and calm them for a few minutes. If I see that this works, I'll definitely do it." N12*

Patient handover involves the transfer of responsibility for patient care to another person, shift, ward, or hospital. Accurate information transfer is the main goal of the patient handover process.

> *"In our ward, the ISBAR technique is used for patient handover. The previous shift provides us with the patient's condition, background, the assessment of the previous shift nurse, and the recommended course of action. Accurate patient handover is of particular importance."* N20

When talking about the patient's environment, the human, physical, and organizational aspects must be considered. The human environment includes all health care providers and other patients. Nurses said that during the shift, in addition to paying attention to their patients, they should be somewhat aware of the condition of other patients in the ward.

> *"When the head-nurse hands over the shift, I usually wonder how complicated this patient's condition is now; for example, how much can they challenge us during the shift?"* N18

Nurses noted that in addition to paying attention to patients, they try to have dynamic communication with the team through sharing patient information with the team, communicating and cooperating with each other, and paying attention to things other treatment team members do.

> *"The relationship among treatment staff is so important. For example, the situation should not be such that the nurse and the physiotherapist do their jobs separately. For example, if the physiotherapist is asked to perform chest physiotherapy and the patient has high ICP, they should be told to restrict some movements."* N7

The physical environment around the patient includes devices and equipment and other environmental conditions such as light, sound, and ambient temperature. Nurses said that due to many pieces of equipment and devices for evaluating and caring for the patient in the ICU, a nurse should be aware of the equipment, its storage, and its usage. At the beginning of each shift, they have to check patients' bedside equipment and connections.

> *"Considering that the patients are intubated, it is very important that the tube is fixed in its position and the ventilator's settings are correct; if there is an IV line then it should be checked, and also, the CV line and NG tube should be examined. I'll definitely check these." N22*

Some nurses said that nurses should also pay attention to light, sound, ventilation, and cleaning.

> *"If the patient is resting, I turn down the light or warn others about the noise so it is quieter."* N10

The organizational environment includes protocols, care measures, and the duties and roles of the nurse. Nurses said that there are specific medical protocols and instructions in the ICU to follow in specific scenarios.

> *"In the ICU, all treatment protocols for common poisonings are put up on the wall in the ward in the form of large posters. In other ICUs, posters for the cardiopulmonary resuscitation algorithm, how to assess the consciousness level with different criteria, blood transfusion instructions, etc. are put up on the wall."* Field note Hospital 1

The nurse and every other member of the team have specific duties and responsibilities for the care and treatment of the patient. Participants stated that the nurse should be aware of their role in the treatment team because due to their constant presence in the ward and patient bedside, they are aware of all the patient's issues and can notice changes and the patient's cues sooner than other treatment team members.

> *"I daresay that because we are a neurosurgery center, the first people that notice the GCS drop of the patient are the nursing staff." N2*

They also said that the nurses are responsible for providing safe and high-quality care to ICU patients.

> *"We do all this so that we don't miss anything about the patient, and there is no necessary measure that we fail to take. The patient's safety should be at the highest level, and they should receive high-quality and safe care."* N19

Main category 2: Comprehension of the current situation: A sense of salience and analysis of cues to achieve a diagnosis

Once you have gathered the information, you need to go beyond it. The next step is to be aware of the situation and comprehend, analyze, or interpret the gathered information. At this stage, a nurse thinks about the information, reasons, and evaluations, and by critically examining the cues, they finally reach a judgment and diagnosis.

Participants said that the nurse verifies the cues after checking the correctness of the observed cues and comparing the observed cues with the patient's basic information.

> *"For example, my patient has a drop in O2 Sat. I will check their pulse oximeter and see if it is working; I check to see if their limbs are cold, and I connect the oximeter to his ear to see if the O2 Sat. is right."* N8

In order to notice the cues, a nurse should know the specific warning signs so that they can distinguish what is normal and what is abnormal. They should know the cues of common complications in the ICU and report them in a timely manner.

> "*Here, the patients' pupils are very important because, through the changes in consciousness and pupil [size], we can notice bleedings that can occur after surgery."* N1

Nurses said that they examine the possible causes of the changes in the patient's condition, prioritizing the patient's main problem, and re-evaluating all systems.

> *"Most of the time, we encounter symptoms that can be similar in different problems. For example, when the capnograph of one of my patients shows that CO2 levels are increasing, the first impulse for me is to say that it's because of COPD, because all our patients are admitted with respiratory issues. However, this rise can be due to fever or hyperthyroidism or . . . "* N5

After critically examining the cues, a nurse puts all the symptoms together to identify the relationship between them by using their knowledge and experience or by reporting the patient's symptoms so that the health care team may diagnose the problem.

> *"... in the tamponade cases that I mentioned, the patient's rhythm goes up, the pressure goes down, and the way they breathe changes. They may even have a state of lethargy in terms of consciousness. Many symptoms help us to recognize and identify the problem"* N25

Main category 3: Projection of future situation: Prediction of patients' status in the near future and environmental foresight

The last cognitive activity that complements situation assessment and awareness is thinking about the future. This ability refers to the use of the obtained conceptual information to extrapolate the situation in the near future. Nurses emphasized that they should make the necessary predictions about the patient's possible condition and the effects of the patient's history (underlying diseases, previous medications, and previous habits) on the patient's condition, in order to take the measures necessary for the patient's near future and keep nursing care ahead of the patient's condition.

> *"A good nurse should always be one step ahead of clinical symptoms. This means that for example, they should be able to predict shock before it happens. The reason for this, is that when the patient is in shock, it will be much harder to bring him out of shock. You can definitely do much better before something happens, and this means that there will be less damage." N7*

> *"Patients who are drug users have very bad prognoses, and they are very restless when they are admitted to the ICU. These patients fight hard when they are connected to the ventilator and have withdrawal signs; they may even fall out of the bed"* N4

> *"At about 10:30 a.m., a 72-year-old patient in bed 2 with a diagnosis of CVA is not hemodynamically stable. A nurse tries to adjust the syringe pump to deliver medication, and a resuscitation trolley has been brought to the patient's bedside."* Hospital 2 field notes

They also stated that the patient's admission to the ICU and the pharmacological and medical treatments always have complications that a nurse should anticipate.

> *"... It is very common for patients to develop emphysema one or two days after surgery before or after the drain is removed, so we check them for emphysema."* N14

In visualizing the future situation and the projection of the patient's near future, the ICU nurse should also have environmental foresight based on the information gathered and prior knowledge of the work environment. Sometimes, due to the complexity of patients' conditions in the ICU, a nurse must expect the patient's condition to change contrary to expectation, sometimes instantaneously.

> *"I cannot say that everything can be predicted because I also believe in miracles. Sometimes you see a patient has a very bad condition, and everyone says he will die, but you see that they become stable."* N10

> *"The ICU is a sensitive department and the patients should be monitored every second because much of these incidents happen in an instant and the nurse should be alert at all times."* N12

The nurses said that a nurse can sometimes predict the conditions of the shift at the beginning of the shift and when entering the ward, relying on intuition, the stability or instability of patients in the ward, the appearance of the ward, relationships between team members and colleagues, and the new patient admissions in the ward.

> *"When we enter the ward, we see that the ward is a mess, one nurse is preparing a patient for a CT scan, another nurse is trying to insert a CV line,... we realize that we are not going to have a good shift."* N16
>
> *"I really don't know, It's a feeling. I can't tell you exactly what it is. But it's a feeling that when I enter the department I can tell that it's going to be a quiet night and eventually, it will be."* N20

Discussion

Dimensions of SA among intensive care nurses based on Endsley's theory include the perception of the elements in the environment, comprehension of the current situation, and projection of the situation into the future; the findings of the study help clarify these abstract dimensions by presenting the characteristics of these dimensions in ICU nurses.

After analyzing the concept of SA in nurses using the Walker and Avant method (2011), Fore and Sculli (2) provided a definition very similar to Endsley's (2). Conducting the present study qualitatively and relying on the theoretical framework helped extract more context-based information about this concept.

In this study, perception was recognized as an essential part of situational awareness, and most of the subcategories and extracted codes were related to this level of SA. The ICU nurses in this study understood the patient's clinical signs through initial and continuous patient evaluation, comprehensive attention to the dimensions of patient health, and attention to patient handover. A nurse simultaneously pays attention to patients, establishes a dynamic interaction with the team, and obtains information on the equipment of the patient and the ward. The nurse also monitors the environmental conditions and physical environment of the ward and keeps in mind the

existing protocols and care measures, their duties and roles, and the organizational environment, as other important elements in the clinical environment.

Sitterding et al. (23) in their study aimed at analyzing the concept of SA in nursing, defined SA as a dynamic process in which a nurse in any clinical environment receives information about the patient and their environment, then understands their meanings depending on the patient, and predicts the necessary interventions (23). Similar to the present study, Sitterding et al. (23) made the collection of patient information the main focus at the perception level.

However, in their study, they referred to the general concept of environment. In contrast, in the present study, in addition to the patient, the human environment, physical environment, and organizational environment were also obtained as other environmental elements in the ICU. Further studies are necessary to examine how different the elements obtained in other wards and situations are from those obtained in this study.

In an ICU, the environment consists of a variety of equipment and a lot of staff. The physical environment, as part of nursing is already embedded in the earliest nursing theories. The physical environment is important for nurses to maintain accessibility to and visualization of the patient (24). Petersson et al. (25) reported that the physical environment, including the medical equipment, workstations, and beds, highly affects ICU nurses' care (25). Also; Gharaveis et al. (26) reported that layout design, visibility, and accessibility levels are the most cited aspects of design that can affect teamwork and the level of communication in healthcare settings (26). Similar to the results of these studies, the nurses of our study also referred to the physical environment, including medical equipment, the location of the patient's bed, lighting, and ventilation for a better understanding of the situation.

Kvande et al. (27) reported in a phenomenological study that nurses in the ICU acquire patients' cues using their senses, measurements, and intuition (27). In the present study, the nurses did not mention intuitive awareness of the patient's symptoms, but in the projection part, they mentioned that they intuitively felt how the shift would go at the beginning of the shift.

The other studies also reported the presence of intuition in care providers in understanding the symptoms and projecting the situation (28, 29). In our study, nurses noted that when they feel the shift will be complicated with their intuition, they try to be more careful in planning and setting care goals from the very beginning.

All health care providers working in acute environments must be able to respond quickly to patient deterioration. Endsley referred to the challenge of obtaining and using relevant data from a data-rich environment as an information gap (30). The present study's findings can be a model to show what information nurses pay attention to in similar environments and how and from what sources they acquire that information.

Research in aviation, driving, and health care has shown that most errors occur at level 1 of SA (10, 31, 32). Endsley emphasizes the importance of design, for example, improving monitor connectors and cockpit design to increase perception in aviation (33). However, the importance of designing the physical space of the ward and using the appropriate equipment can also be extended to the ICU.

Although much of the data in health care comes from other people, patients, caregivers, and colleagues, it cannot be improved through design, but targeted educational interventions may improve SA. We will be able to provide techniques to strengthen this level of SA through increasing awareness of what SA is and how it affects performance, and teaching strategies to improve data collection, focus, situational sensitivity, communication, and coordination.

In their review, Massey et al. (34) point out that recognizing and responding to patient deterioration is complex, challenging, and multifaceted and requires the identification and combination of multiple symptoms of patients. Knowing the patient led to a sense of salience and an ability to recognize aspects of the patient's clinical situation, which is important for ward nurses' judgment (34).

In this study, nurses said that prior knowledge of the patient, comparison of current cues with baseline cues, and recognition of warning signs of the disease lead to a sense of salience and importance of the cues, and, finally, diagnosis of the patient's current situation.

The sense of salience is an ability to recognize the subtle changes in a situation acquired through understanding and knowing the patient's deep background (35). In a thematic study, Lavoie et al. (36) have identified surveillance, recognition, referral, and response as four processes related to patient deterioration in the ICU that require careful evaluation and surveillance during the monitoring phase. In the recognition phase, the data are interpreted, and in the referral phase, nurses communicate with other clinicians by conveying the data to determine the appropriate therapeutic interventions, which is confirmed by the results of the present study (36). Because the nurses could not perform some interventions and prescribe medications themselves, they said that a physician should make a final diagnosis.

In addition to problem diagnosis, there is a concept of nursing diagnosis in the nursing literature. Nurses use nursing diagnoses to accurately share patient health problems, high-risk situations, and patient readiness for health promotion (37). However, in the present study, nurses did not mention this concept, which is probably due to the lack of awareness of the nurses who participated in the present study of the importance of this concept in care. In field observations, it was also observed that nursing diagnoses were mentioned routinely and in many similar cases in nursing reports.

The study results by Juvé-Udina et al. (38) indicate that the high number of nursing diagnoses in the ICU might reflect

poor prioritization and a linear decision-making process, and problem perception regardless of the complete situation of the patient (38).

Future studies need to investigate the relationship between nursing diagnoses for the patient and SA in ICU nurses.

Level 3 is the highest level of SA and is the level at which health care providers project the patient's expected condition, which is critical to achieving treatment goals through managing the treatment process and adequacy of resources. ICU nurses work in a very complex and technical environment, and some conditions are highly unpredictable and require the ability to accurately identify and change priorities rapidly (27).

However, there are criteria for predicting the patient's deterioration and mortality rate. In the present study, ICUs use the Failure Organ Sequential Assessment (SFOA) and APACHE II criteria to predict the mortality and severity of patients' conditions. However, in the worksheets, these cases were evaluated by an ICU physician, and participants did not refer to them to predict patients' conditions.

Nevertheless, they referred to criteria such as the Braden Scale to determine the risk of pressure ulcers and the Morse Fall Risk Assessment to predict certain conditions. Kim et al. (39) point out in their study that although the warning scores of these criteria may be useful in identifying at-risk patients, direct examinations and ongoing surveillance by health care providers should be emphasized (39).

Nurses who participated in the present study also stated that a nurse should always be "attentive" in order to be ahead of the patient in terms of nursing care by projecting the patient's condition to prepare the environment for emergencies to control the situation. Through environmental foresight and predicting the patient's status into the near future, a nurse anticipates sudden changes in circumstances contrary to the expected conditions and predicts work shift conditions.

Limitation and strengths of the study

Participants may, in some cases, have stated what they knew rather than what they did; attempts were made to interview informed people and those who were willing to participate in the study, and the observation method was also used to collect data. On the other hand, it is difficult to comment on our findings due to the lack of similar studies for comparison.

Despite these limitations, we argue that the insights and knowledge gained from this study can be useful for future practice, education, and research. For future studies, to develop and explain this concept, it is suggested that similar studies be conducted on other members of the health care team and other health settings.

Conclusion

Findings obtained according to Endsley's SA model further developed this cognitive concept among ICU nurses. This study provides a practical and contextual definition of SA in ICU nurses. SA was experienced in ICU nurses as follows; first, a nurse understands the elements in the clinical environment, including human, physical and organizational aspects of the environment, through perception of clinical cues of the patient and their environment. Then, using the sense of salience, i.e., giving importance to the cues and analyzing and interpreting the received cues, the nurse becomes able to comprehend the patient's current situation. Finally, through environmental foresight and the prediction of patients' status in the near future, they can project the future situation.

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 Shahid Beheshti University of Medical Sciences. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RE and AE supervised this study. RE, AE, and CG designed the study and cooperated in composing, reviewing, and correcting the written version. AE and CG prepared the interview guide. CG conducted the interviews. RE and CG analyzed the interviews. All authors contributed to the article and approved the submitted version.

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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.2022.999745/full#supplementary-material

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EDITED BY
Xuelei Ma,
Sichuan University, China

REVIEWED BY
Guillaume Hache,
Aix Marseille Université, France
Dalia Almaghaslah,
King Khalid University, Saudi Arabia

*CORRESPONDENCE
Mohamed N. Al Arifi
malarifi@ksu.edu.sa

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Perception of pharmacy students toward numeracy: An observational study from King Saud University, Riyadh Saudi Arabia

Ziyad Alrabiah, Azher Arafah, Muneeb U. Rehman, Wajid Syed, Salmeen Babelghaith, Abdulrahman Alwhaibi, Sultan Alghadeer, Abdulaziz Alhossan and Mohamed N. Al Arifi*

Department of Clinical Pharmacy, College of Pharmacy, King Saud University, Riyadh, Saudi Arabia

Background and objective: Numeracy is the branch of mathematics involved in understanding basic calculations, quantitation, estimation, reasoning, and execution of multistep operations. It is very imperative that pharmacists understand and apply numeracy skills in their routine work in the interest of their profession and patient care. This observational study was designed to assess the pharmacy student's perceptions of numeracy.

Methods: A prospective observational study was conducted by the Department of Pharmacy, King Saud University, Kingdom of Saudi Arabia, between December 2021 and February 2022. All the enrolled subjects pursued a 5-year Pharma degree course at the university using a 9-item instrument, which accessed the perception of students toward numeracy. The data were analyzed using the statistical software statistical package for social science (SPSS) version 26.0 (SPSS Inc., Chicago, IL, USA). Chi-square and Fisher's exact test were used to derive an association between various parameters of the study subjects. A P-value of <0.05 was taken as statistically significant.

Results: A total of 550 pharmacy students were approached in this study, out of which 21 (3.8%) students were excluded due to incompleteness of the responses; thereupon, 529 students were included in the study. We learned that almost 90.0% of students had excellent and/or good mathematical ability, but at the same time, they were frequent users of calculators. Most of the students endorsed the importance of numeracy and showed their interest in attaining more knowledge of numeracy. Similarly rating the perceptions of mathematical ability is significantly associated with the frequency of use of a calculator for calculations ($p = 0.0001$).

Conclusion: Pharmacy students showed interest in numeracy and correspondingly showed excellent perceptions toward mathematical ability. Although the role of numeracy has been well accepted, inciting changes in teaching-learning practices through mathematically focused teaching

approaches throughout the pharmacy program will increase its applicability in healthcare.

KEYWORDS

numeracy, pharmacy students, Saudi Arabia, perceptions, health care

Introduction

Mathematics plays an interdisciplinary role in medical, biological, chemical, physical, and earth sciences (1), and its application extends to pharmacy courses. Due to its importance, mathematics is a crucial subject in the pharmacy curriculum. Mathematics provides knowledge and skills vital in altering technological scenarios (2). Numeracy is proficiency in mathematics or the ability to use or apply mathematics. Numeracy includes all those skills needed to decipher appropriate mathematical models for solving fundamental and intricate problems, especially in medical sciences (3). Inadequate numeracy knowledge has been associated with worse health indicators and consequences, including increased hospitalizations, inferior disease diagnostic facilities, more significant occurrence and severity of chronic diseases, non-adherence to higher medication, and lesser health behavior engagement (4, 5). Limited numeracy skills are also associated with lesser knowledge of disease risk factors (6, 7).

The quality of numeracy of pharmacy students was first questioned in 2000, after "The Peppermint Water case," which led to the death of a 3-week-old boy in 1998, due to the addition of the excess amount of chloroform, by a pharmacist, to peppermint water prescribed to treat colic of a 4 days old baby. This incident raised queries about the knowledge and readiness of pharmacy undergraduates regarding the calculation of quantities of constituents in medication (8). Subsequently, it has been described that pharmacy students have lower numeracy skills at university levels and almost rely on calculators leading to skewed calculations and an inability to solve numerical problems encountered during and after the completion of the course (9). Keeping in view the importance of numeracy, the Royal Pharmaceutical Society of Great Britain (RPSGB), The Pharmaceutical Society of Northern Ireland (PSNI), and The School of Pharmacy at Queen's University Belfast (QUB) have introduced an obligatory section containing numerical questions in the entrance exam paper of pharmacy degree course way back in 2002, 2005, and 2010, respectively (10).

As per previous studies, competence in mathematics plays a significant role in forecasting the success of pharmacy institutes (11). Basic math skills have been linked previously to academic enactment among pharmacy students (12, 13). Many studies reported that pharmacists could employ their numeracy skills as part of their professional practice in dispensing and compounding dosage forms, ultimately leading to better patient care (14, 15). Studies have shown a higher frequency of calculation deficiencies and relatively decreased mathematical ability in medical students, undergraduate pharmacy students, and doctors (16–18). Therefore, a good grasp of numeracy is fundamental to allow healthcare professionals, especially pharmacists, to use this knowledge for executing mathematical functions such as drug-dose calculations (19).

Thus, this study aimed to evaluate the numeracy skills of pharmacy students seeking their undergraduate degree course at King Saud University, Saudi Arabia. Additionally, students' level of confidence and attitude toward mathematics was assessed, which will ultimately perceive their mathematical performance. This study would identify simple indicators to better understand how pharmacy institutions and educators can appraise themselves to achieve academic excellence. Therefore, this study aimed to assess pharmacy students' perceptions of numeracy.

Materials and methods

Study design

It was a prospective observational study conducted by the Department of Pharmacy, King Saud University, Kingdom of Saudi Arabia, between December 2021 and February 2022. All the enrolled subjects pursued a 5-year Pharma degree course at the university.

Questionnaire

The questionnaire used for this study was adopted based on previous studies published in a similar context (13, 14). The questionnaire was designed initially in the English language to assess the perceptions of Pharmacy students toward numeracy; then, the questionnaires were translated into the Arabic language with the help of native Arabic speakers using forward and backward translation procedures. The questionnaire was divided into two parts. In the first part, the socio-demographic data such as age, gender, pharmacy year, and nationality were recorded. The second part of the study contained one item asking for the rating of student perceptions toward their

mathematical skills (excellent/fair/good/poor). The third part of the study asks participants nine multiple-choice questions to access students' perceptions of numeracy. Before beginning the study, first, a research specialist in the associated field evaluates the first draft of the tool, second, a pilot study was done with a randomly selected sample of 20 students to get their feedback. The final draft of the questionnaires was distributed and translated into the local language with help of native Arabic speakers then the tool was sent to the intended participants, with changes based on the pilot research. The reliability test was performed using SPSS to calculate Cronbach's alpha, and a value of 0.70 suggested questionnaires adequate for the study. The pilot study's data were not used in the final analysis.

Statistical analysis

The data were analyzed using the statistical software SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). Chi-square and Fisher's exact test were used to derive an association between numeracy and socio-demographic parameters of study subjects. A *P*-value of <0.05 was taken as statistically significant.

Results

Study participants

A total of 550 pharmacy students were approached in this study, out of which 21 (3.8%) students were excluded due to incompleteness of the responses; thereupon, 529 students were included in the study. The response rate of pharmacy students in the study was 96% and included those who thoroughly answered the questionnaires. Out of 529 subjects, 288 (54.4%) were men and 236 (44.6%) were women. The majority of study subjects were aged between 18 and 25 years (96.2%). Fifty-three (10.0%), 84 (15.9), 102 (19.3), 78 (14.7), 68 (12.9), and 144 (27.2) subjects enrolled in the study were studying in the first, second, third, fourth, fifth, and last year of pharmacy course. Most enrolled subjects were Saudi nationals 512 (96.7%). Characteristics of participants are shown in Table 1.

TABLE 1 Characteristics of study participants.

Variables	$N = 529$ (%)
Gender	
Male	288 (54.4)
Female	241 (45.6)
Age group	
>18 years	07 (1.3)
18–25 years	509 (96.2)
26–30 years	13 (2.5)
Pharmacy year	
First	53 (10.0)
Second	84 (15.9)
Third	102 (19.3)
Fourth	78 (14.7)
Fifth	68 (12.9)
Final	144 (27.2)
Nationality	
Saudi	512 (96.7)
Non Saudi	17 (3.2)

The attitude of pharmacy students toward numeracy

The response of Pharmacy students to various questions about numeracy is given in Table 2. According to our survey, the majority of the students (461 of 529; 87.1%) agreed that they study "A" grade mathematics during their pharmacy course, while 77.7% (411 of 529) agreed that they learn numeracy during graduation. Regarding the importance of mathematical calculations in the future, most of the students endorsed its importance (428 of 529; 81.0%). In this study, more than half of the students sometimes used a calculator for carrying out calculations (313 of 529; 59.2%), while 37.3% (197 of 529) used it always, and only 3.2% (17 of 529) used calculators rarely. Regarding teaching numeracy skills in college, there was a mixed response among students. When asked about the support provided by the college in solving mathematical problems, 28.9% responded positively and 24.3% responded negatively. Nearly 40.0% of the students revealed that there should be more emphasis placed on pharmaceutical calculations within the Pharma degree course. Additionally, 41.4% of students believed that they would benefit from extra classes in basic mathematics. When asked about the ability to perform mathematical calculations in the pharmacy degree course, 34.8% of them reported an increased ability to perform calculations, while as 48.4% reported no change (Table 2).

Association between frequency of calculator use and characteristics of study subjects

Table 3 describes the association between the frequency of use of the calculator and the characteristics of study subjects. The findings reported no significant association between students' characteristics and the frequency of calculator use ($P > 0.005$). Similarly, studying a level of mathematics is not significantly associated with the frequency of calculator use ($p > 0.005$).

Rating of student perceptions toward their mathematical skills and characteristics of participants

Perceptions of students undergoing pharmacy undergraduate degree courses toward their mathematical skills were categorized into Excellent, Fair, Good, and Poor. We observed that almost one-third of study participants believed that they had excellent perceptions toward mathematical ability (31.6%; 167 of 529), more than half had good (58.8%; 311 of 529); 8.8% (47 of 529) had fair, and only 0.8% (04 of 529), respectively (Figure 1). Subsequently, Table 4 shows a rating of student perceptions toward their mathematical skills and characteristics of participants. We did not find any significant association between them ($P > 0.005$). Similarly rating the perceptions of mathematical ability is significantly associated with the frequency of use of a calculator for calculations ($P = 0.0001$) as shown in Table 4.

TABLE 2 Perceptions of pharmacy students toward numeracy.

Questions	$N = 529$ (%)
Did you study A-level math?	
Yes	461 (87.1)
No	68 (12.9)
Did you learn about numeracy? (mathematical calculations in healthcare)	
Yes	411 (77)
No	111 (20)
Do you feel that the ability to perform mathematical calculations will be important to you as a future doctor?	
Yes	428 (81.0)
No	101 (19.0)
How often do you use a calculator when carrying out calculations?	
Always	197 (37.3)
Sometimes	313 (59.1)
Rarely	17 (3.2)
Never	02 (0.4)
Do you feel that there is adequate teaching provided by your college in relation to numeracy skills needed to complete the bachelor's degree?	
Yes	295 (56.0)
No	234 (44.0)
Do you think there is sufficient support within your college in relation to problems encountered by a student with calculations?	
I do not know	248 (46.8)
Yes	153 (28.9)
No	128 (24.3)
Do you think there should be more of an emphasis placed on pharmaceutical calculations within the Pharma degree course?	
I do not know	140 (25.4)
Yes	208 (39.4)
No	181 (34.2)
Do you feel that you would benefit from extra classes in basic mathematics?	
I do not know	158 (29.8)
Yes	219 (41.4)
No	152 (28.8)
Since starting your bachelor's degree do you feel more or less able to perform mathematical calculations?	
Less able	89 (16.8)
More able	184 (34.8)
No change	256 (48.4)

Discussion

This study was conceived to understand the perception of pharmacy students toward numeracy and to deduce their mathematical ability. Previous studies have examined the extent to which mathematical ability correctly recognizes individuals with insufficient health knowledge compared to a benchmark (20). Others studies have related measures of numeracy (21) or compared measures of health literacy and numeracy (22). Such assessments are planned to help researchers and healthcare providers identify pharmacy students with inadequate health literacy so that timely interventions could be made for the production of a well read breed of pharmacists. There are many occasions, where public pharmacists utilize their mathematical ability as a part of their professional expertise. These comprise dose measurement, and calculating quantities and concentrations. It is, therefore, very much imperative that pharmacists are able to do calculations precisely and habitually so as to safeguard patient safety and the reputation of their profession. The RPSGB Accreditation Document (23) and the QAA subject benchmark statement for pharmacy (24) have made pharmaceutical numeracy mandatory for the attainment of a pharmacy degree.

The age group of study subjects was between 18 and 30 years as the target population was pharmacy students undergoing undergraduate degree courses. In our study, student feedback was recorded in response to the battery of nine questions. Feedback is a serious element of the learning process (25). Nonetheless, making the best use of feedback opportunities would likely increase students' learning opportunities (26).

In our survey, almost 90.0% of pharmacy students had studied A-level maths before entering into pharmacy courses which are in line with the study done in Northern Ireland (14). Our observation is in disparity with a previous study from a pharmacy school that observed a decline in the proportion of entrants with A-level maths over recent years (18). As studies have observed a fall in numeracy standards of university entrants (27) many concerns have been raised about the decline in the

TABLE 3 Association between the frequency of use of calculator and characteristics of study subjects.

Demographics	$N = 529$ (%)	Frequency of use of calculator when carrying out calculations				
		Always 197 (37.3)	Sometimes 313 (59.1)	Rarely 17 (3.2)	Never 02 (0.4)	*P*-value
Gender						0.5
Male	288 (54.4)	119 (41.3)	159 (55.2)	09 (3.1)	01 (0.3)	
Female	241 (45.6)	78 (32.2)	154 (64.0)	08 (3.4)	01 (0.4)	
Age group						0.424
>18 years	07 (1.3)	02 (28.6)	04 (57.1)	01 (7.7)	00 (0.0)	
18–25 years	509 (96.2)	191 (37.5)	301 (59.1)	15 (2.9)	02 (0.4)	
26–30 years	13 (2.5)	04 (30.8)	08 (61.5)	01 (7.7)	00 (0.0)	
Pharmacy year						0.128
First	53 (10.0)	20 (37.7)	31 (58.5)	02 (3.8)	00 (0.0)	
Second	84 (15.9)	27 (32.1)	52 (61.9)	05 (6.0)	00 (0.0)	
Third	102 (19.3)	29 (28.4)	71 (69.6)	02 (2.0)	00 (0.0)	
Fourth	78 (14.7)	28 (35.9)	49 (62.8)	01 (1.3)	00 (0.0)	
Fifth	68 (12.9)	26 (38.2)	38 (55.9)	04 (5.9)	00 (0.0)	
Final	144 (27.2)	67 (46.5)	72 (50)	03 (2.1)	02 (0.4)	
Did you study A-level maths?						0.292
Yes	461 (87.1)	168 (42.6)	274 (59.4)	17 (3.7)	02 (0.4)	
No	68 (12.9)	29 (42.6)	39 (12.5)	0 (0.0)	0 (0.0)	

number of students taking mathematics as an A-level subject at intermediate levels (28). As most of our pharmacy course entrants were well versed in previous math courses, they were fully prepared for entry into practice in the community. The statement that entry qualifications are a predictor for numeracy proficiency is consolidated by the fact that almost all the pharmacy school entrants had acquired A-level math training in their intermediates and subsequently they performed very well during the period of their degree. Currently, universities complying with regulatory body requirements for pharmacy courses merely need to warrant that the selection criteria of students inculcate basic numeracy skills.

Almost 90.0% of pharmacy students were of the opinion that the ability to perform mathematical calculations will be important as a future doctor. The results demonstrated that students adored mathematics as they realized its scope in medical sciences. Our observations are in coherence with the study by Van der Bergh (29) who found a significant influence of students' interest on the ability to successfully learn and apply mathematics in medical science. The study of Syyeda (30) also backs our outcome that students cherished mathematics. In contrast, a previous study on nurse and midwifery students highlighted that students had a negative attitude toward mathematics and lacked numeracy skills (19) which are further supported by findings of Axe (31) and Wright (32). Various approaches to enhance the interest of pharmacy students in numeracy and to instill confidence have been adopted which include the introduction of numeracy tests in formative assessment and this approach has been found to increase numeracy skills (33).

It was noteworthy that the majority of pharmacy students feel that they would benefit from extra classes in basic mathematics. With the addition of new subjects to the B. Pharma Program, the implementation of extra classes is rather difficult in view of time constraints. However, the university is planning to supplement the students with online supplementary material on applied mathematics thereby improving the numeracy standards. This supplementary material will provide further instruction in basic numeracy and pharmaceutical calculations necessary for better implementation of pharmacy in day-to-day life (14).

In our study, only around 4.0% of students rarely and/or never used calculators (Table 3). Previous data reveals that the use of calculators resulted in an enhanced inclination toward mathematics (34) which provided the impetus for mentors to teach and examine students using this tool. A study by Chamblee et al. reported a significant improvement in the exploration and implementation of technology through the use of graphic calculators (35). Another study reported the beneficial use of calculators to pharmacy students with a basic knowledge of mathematical facts (36). Individual's belief is one of the strongest factors responsible for the low use of calculators (37). Thus, we as teachers, educators, and healthcare providers must have a positive attitude toward the use of gadgets

TABLE 4 Association between the rating of perceptions toward mathematical ability and characteristics of participants.

Demographics	$N = 529$ (%)	Rating of perceptions toward mathematical ability				
		Excellent 167 (31.6)	Good 311 (58.8)	Fair 47 (8.8)	Poor 04 (0.8)	*P*–value
Gender						0.48
Male, *n* (%)	288 (54.4)	102 (35.4)	162 (56.3)	22 (7.6)	02 (0.7)	
Female, *n* (%)	241 (45.6)	65 (26.3)	149 (61.9)	25 (10.6)	02 (0.8)	
Age group						
>18 years, *n* (%)	07 (1.3)	03 (42.9)	04 (57.1)	00 (0.0)	00 (0.0)	0.15
18–25 years, *n* (%)	509 (96.2)	159 (31.3)	303 (59.5)	44 (8.6)	03 (0.6)	
26–30 years, *n* (%)	13 (2.5)	05 (38.5)	04 (30.8)	03 (23.1)	01 (7.7)	
Pharmacy year						
First, *n* (%)	53 (10.0)	15 (28.3)	33 (62.3)	05 (9.4)	00 (0.0)	0.594
Second, *n* (%)	84 (15.9)	35 (41.7)	46 (54.8)	03 (3.6)	00 (0.0)	
Third, *n* (%)	102 (19.3)	36 (35.2)	55 (54.0)	10 (9.8)	01 (1.0)	
Fourth, *n* (%)	78 (14.7)	23 (28.4)	44 (56.5)	10 (12.8)	01 (1.3)	
Fifth, *n* (%)	68 (12.9)	20 (29.4)	44 (64.7)	04 (5.9)	00 (0.0)	
Final, *n* (%)	144 (27.2)	38 (25.7)	89 (61.8)	15 (10.4)	02 (1.4)	
Frequency of use of calculator when carrying out calculations						0.0001
Always, *n* (%)		43 (26.1)	122 (39.2)	29 (61.7)	02 (50.0)	
Sometimes, *n* (%)		112 (67.9)	183 (58.8)	16 (34.0)	01 (25.0)	
Rarely, *n* (%)		09 (5.5)	06 (1.9)	02 (4.3)	0.0 (0.0)	
Never, *n* (%)		0.0 (0.0)	0 (0.0)	0.0 (0.0)	1.0 (25.0)	

such as calculators to make mathematics meaningful and more applicable to disciplines like medicine and pharmacy in which not only accuracy but the time needed to perform calculations is very much decisive to safeguard the life and interests of a patient.

In our study, the mathematical ability of more than 90.0% of pharmacy students has been rated as either "good" or "excellent" (Table 4). In order to enhance the mathematical ability and to increase the behavioral and cognitive learning of pharmacy students the factors of Walberg's Theory of Productivity should be considered (38, 39). The first group of factors includes aptitude variables that cover students' drive and prior accomplishments. The second group of factors includes those instructional habits that affect students' wisdom of mathematics, especially the amount and superiority of directions. The amount of directions is defined by the extent of time students spend learning mathematics. The superiority of directions includes the degree to which the topic is clear to students, various aspects of presentation, and clarity of language (39). Psychological or environmental factors comprise the last group of factors influencing mathematical ability (39, 40). Lack of mathematical ability among pharmacists is worrisome since it could result in serious errors in dose calculations, considering today's students are tomorrow's professionals (41–44) leading to dire consequences and even the death of the patient (19).

On stratification, we found that first- and second-year pharmacy students and students of younger age groups had higher mathematical ability compared to their seniors which deduce that more attention toward numeracy and pharmaceutical calculations be paid to students in their B. Pharma Program. Our findings may be due to the fact that first- and second-year students receive extensive instruction and classes in numeracy and more than 8 h of teaching time per week is dedicated to numeracy at the beginning of the Program followed by a multiple-choice assessment to check the progress. In addition, first- and second-year pharmacy students are taught mathematics properly for efficient dose measurement and dispensation. During the last years of the pharmacy Program, numeracy calculations performed by students are applicable to day-to-day life rather than the basic calculations used for dose measurements (14). In contrast to our observations, previous studies have reported that first-year midwifery and nursing students had relatively lower mathematical ability (45–47) which hints toward the fact that students entering midwifery and nursing courses lack basic numeracy skills and concepts which

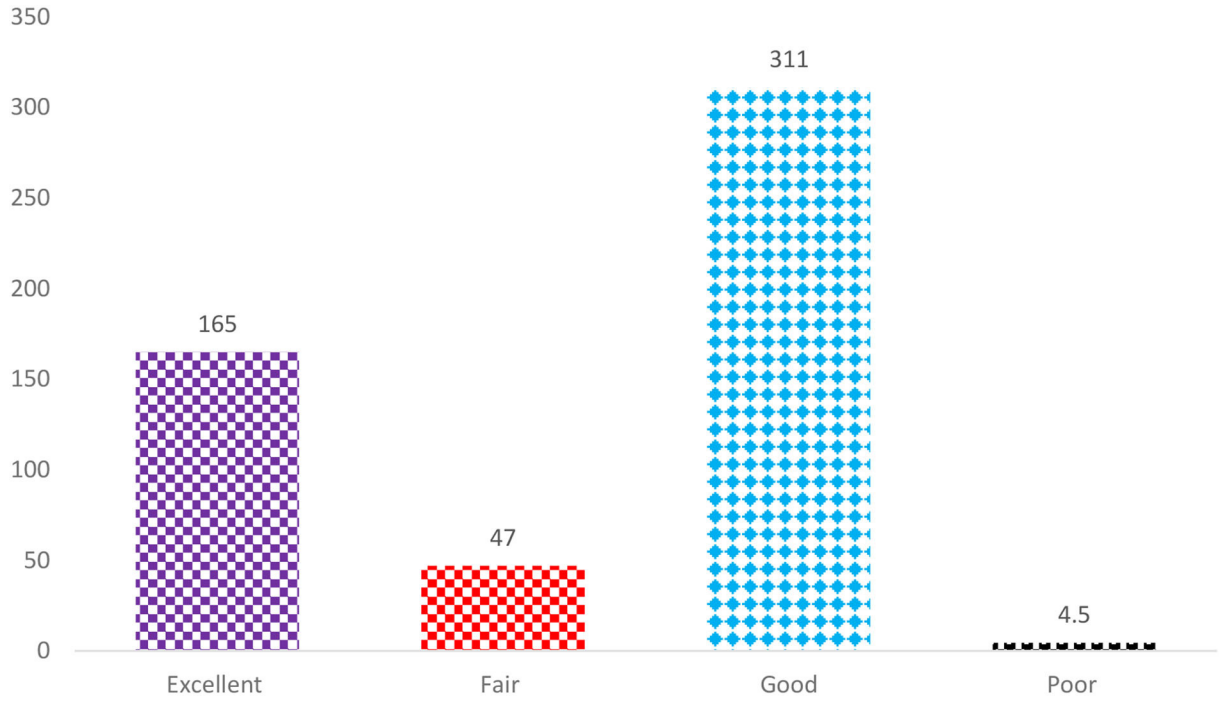

FIGURE 1
A rating of student perceptions toward their mathematical skills.

may be due to the fact that they did not receive A-level math's training in their intermediate before entering nursing school.

Limitations of the study

In our study, only self-reporting was noted. In order to do away with this limitation in the future, we would include more than one data source, i.e., data collected through classroom observations; teacher reports; transcripts; and grades of students.

Conclusion

Competence in numeracy is a requirement for many regulatory accreditation bodies and is necessary for the pharmacy curriculum. According to a self-estimated questionnaire, the pharmacy students had a positive attitude toward numeracy and exceptional or good mathematical ability. Regarding the importance of mathematical calculations in the future, most of the students endorsed its importance additionally more than half of the students sometimes used a calculator for carrying out calculations. Slightly less than half of the students revealed that there should be more emphasis placed on pharmaceutical calculations within the Pharma degree course. Lack of numeracy among pharmacy undergraduate students might increase the risk of potential patient harm once they enter clinical practice. Teachers need to warrant that proficiency in numeracy is reflected while practicing pharmacy and, at the same time, ensure full support to students. This is likely achieved with problem-based teaching practices and a correctly constructed curriculum.

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 human participants were reviewed and approved by IRB-E-21-6348. The patients/participants provided their written informed consent to participate in this study.

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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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EDITED BY
Yihui Du,
University Medical Center Groningen, Netherlands

REVIEWED BY
Ming-Chieh Li,
National Taiwan Normal University, Taiwan
Miao Cai,
School of Public Health, Sun Yat-sen University, China
Xiaomin Song,
BeiGene, China

*CORRESPONDENCE
Lei Guo
kakulayi177@163.com
Yixuan Liu
liujinmin789@tom.com
Qiushi Zhang
zhangqsh@gd2h.org.cn

†These authors have contributed equally to this work

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Association between sedentary time and metabolic syndrome: A cross-sectional study among Chinese Garze Tibetans

Lei Guo[1*†], Yixuan Liu[1*†], Tingting Xue[1], Liang Liang[2], Yongcuo Nima[2], Yang Yang[1], Qun Li[1] and Qiushi Zhang[1*]

[1]Guangdong Second Provincial General Hospital, Guangzhou, China, [2]Garze Tibetan Autonomous Prefecture People's Hospital, Kangding, China

Background: Chinese Tibetans have long hours of sitting without much physical activity given their religious behavior, raising potential harmful health hazards. However, the relationship between sedentary time and metabolic syndrome (MetS) has not been investigated in Chinese Tibetans.

Methods: From Jan 2021 to Jun 2022, residents in Garze Tibetan Autonomous Prefecture in Southwest China's Sichuan province were recruited using a multi-stage, stratified, random-cluster sampling strategy. MetS were ascertained using definition proposed by the International Diabetes Federation. Associations between sedentary time and the prevalence of MetS in the total sample and by age and sex were estimated using logistic regression models.

Results: Among 971 Chinese Tibetan participants (mean age 41.1 years and 73.8% female), 319 (32.9%) were diagnosed as having MetS. We found positive associations of sedentary time over 11 h per day with the prevalence of MetS in crude (OR: 1.23; 95% CI: 1.12–1.36, $p < 0.001$), age and sex adjusted (OR: 1.18; 95% CI: 1.08–1.29, $p < 0.001$), and fully adjusted (OR: 1.17; 95% CI: 1.08–1.29, $p < 0.001$) models, compared to those who had <8 h of sedentary time per day. Sensitivity analyses suggest consistent positive association between sedentary time and each metric of MetS.

Conclusions: Sedentary time longer than 11 h per day is significantly associated with increased risk of MetS, suggesting that polices to advocate health education may alleviate the health burden of MetS among Tibetans in China.

KEYWORDS

sedentary time, metabolic syndrome, Tibetans, Chinese, cross-sectional study

Introduction

Metabolic syndrome (MetS) is a constellation of metabolic disorders including dyslipidemia, elevation of arterial blood pressure, and impaired fasting glycemia (1, 2). Numerous organizations including the World Health Organization and International Diabetes Federation have acknowledged MetS as a major risk factor for cardiovascular

diseases and diabetes. Accompanying the temporal trend of obesity across the world, the fast grow in incidence and prevalence of MetS poses a significant health challenge that requires prompt and effective plans to cope with (3–5).

Similar to the global surge of MetS, the incidence and prevalence of MetS have also been rapidly increasing in the past 20 years in China, owing to miraculous economic growth, expeditious urbanization, adoption of Western pattern diet and sedentary lifestyle (3, 5–8). Tibetans are a special minority Chinese ethnicity group who live in high-altitude, sparsely populated, and less economically developed Western areas (9). Residents in Tibet mostly believe in Tibetan Buddhism and have a long ritual practice of meditation and chanting, resulting in long hours of sitting without much physical activity and potential negative health impacts (10–12). However, there is little evidence on the potential health effects of sedentary lifestyle on MetS in Tibetans Chinese.

Characterizing the relationship between sedentary time and MetS among Chinese Tibetans helps gain insights into a minority group and socially disadvantaged population in Western China. This could further help marching toward the Sustainable Development Goals (SDG) 3 of ensuring healthy livelihood and improve the wellbeing for all people including those disadvantaged groups (13–17). In this large cross-sectional study including 971 residents who live in Garze Tibetan Autonomous Prefecture, Sichuan province, we collected numerous demographic, behavior, and laboratory measure data on the participants. We aim to understand the relationship between sedentary lifestyle and the prevalence of MetS, as well as potential effect modifications.

Methods

Sampling strategies and participants

Garze Tibetan Autonomous Prefecture is in Southwest China's Sichuan province. From Jan 2021 to Jun 2022, a representative sample of individuals aged 18 years and over was enrolled to investigate the prevalence and risk factors of chronic disease. This investigation used a multi-stage, stratified, random-cluster sampling strategy. Three counties in the prefecture (Garze, Shiqu, and Seda) were selected first (Figure 1). In the second stage, Garze town in Garze county, Niga town in Shiqu county, and a Buddhist college (Larung Gar Buddhist Academy) in Seda county were randomly selected. All the eligible individuals 18 years and older were included. In total, we included 1,416 subjects with information about serum uric acid and medical history out of 3,093 subjects overall. This study was approved by the Ethics committee of Guangdong Second Provincial General Hospital (20201229-KJBF-02-01). All of the participants in this study signed an informed consent form.

Data collection

A face-to-face interview was performed by trained doctors and nurses to collect demographic characteristics (age, sex, and education), lifestyle behaviors (smoking status, drinking status, and physical activity), anthropometric measurement (body mass index [BMI], waist circumference, and blood pressure). Education was divided into three levels (college or above, high school or equivalent, and less than high school). Physical activity was defined as $\geq$75 min of vigorous activity per week or $\geq$150 min of moderate activity per week (18). Smoking status and drinking status was classified into never or previous/current. Physical measurements (height, weight, and waist circumference) were measured by trained nurses. BMI was calculated by dividing the weight in kilograms by the height in meters squared. Blood pressure (including systolic blood pressure [SBP] and diastolic blood pressure [DBP]) of the participants was measured two times by a standardized automatic electronic sphygmomanometer after at least 5 min of rest in a seated position. A total of 5 mL venous blood samples of fasting blood were drawn by trained nurses in the morning and sent to the laboratory to evaluate the biochemical parameters, including comprising fasting blood glucose, triglycerides, total cholesterol (TC), LDL-cholesterol (LDL-C), and HDL-cholesterol (HDL-C).

MetS

In line with the definitions made by the International Diabetes Federation and a few previous studies (19, 20), MetS is defined as people with abdominal obesity who meet at least two of the following four criteria: triglycerides $\geq$1.7 mmol/L; HDL-C $<$ 1.03 mmol/L for male or $<$1.29 mmol/L in female; SBP $\geq$130 mmHg or DBP $\geq$85 mmHg; fasting glucose $\geq$5.6 mmol/L. Waist circumference was used to describe abdominal obesity ($\geq$85 cm for male or $\geq$80 cm for female) according to Chinese guidelines (20).

Sitting time

The sitting time was assessed according to the question "How many hours do you usually sit in 1 day?". The response scale contained 4 options: (1) $<$8 h; (2) 8–9 h; (3) 10–11 h; and (4) $>$11 h.

Statistics analyses

Pearson Chi-square tests were used to explore the connection between categorical variables and the *T*-tests were applied to examine the differences of continuous variables

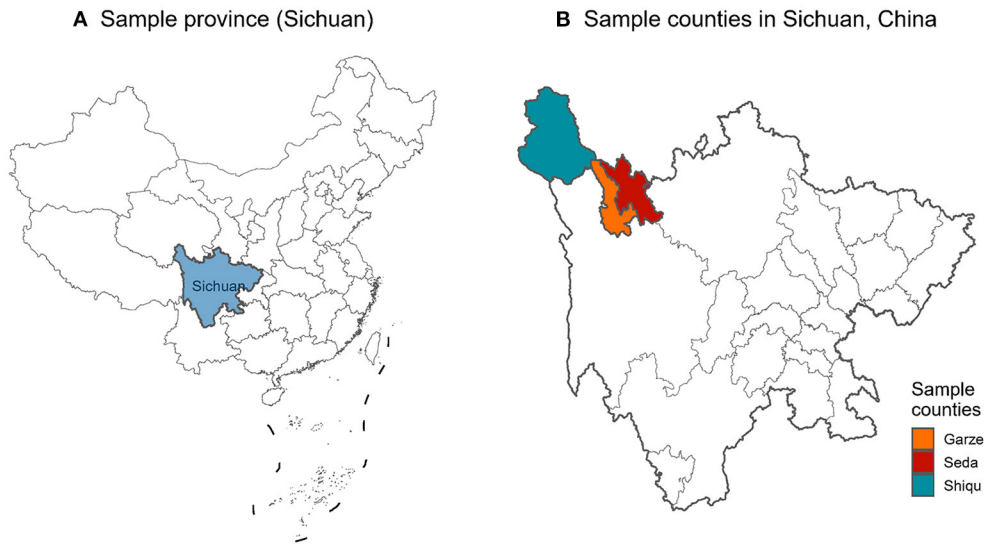

FIGURE 1
Geographic locations of the sample counties in Sichuan province, China. **(A)** Sample province (Sichuan). **(B)** Sample counties in Sichuan, China.

between MetS groups in this study. We calculated the odds ratio (OR) for MetS by using a series of logistic regression models based on the sitting time and other covariables. Three models were conducted: crude model including sitting time only; basic model adjusted for age and sex; and fully adjusted model additionally accounted for the other independent variables, including education, smoking status, drinking status, BMI, and physical activity.

We further conducted subgroup analyses by sex (male and female) and age (<40 and ≥40) to examine potential effect modifications. The interaction term of the stratifying covariate with sitting time was implemented to test the differences between subgroups (21).

To test the robustness of our findings to each metric of MetS, we estimated the associations between sedentary time and each measure of MetS (abdominal obesity, triglycerides, HDL-C, hypertension, and hyperglycemia) in separate logistic regression models.

All statistical analyses were performed using R software, version 3.6.1. $P < 0.05$ was considered statistically significant.

Results

Sample characteristics and the prevalence of MetS

Table 1 shows the demographic information and laboratory test results of the 971 participants involved in this study and stratified by the status of Metabolic syndrome. Among the overall participants, 319 (32.9%) were diagnosed as having MetS according to our definitions. The participants were middle-aged (mean age 41.1 years), mostly female (73.8%), lack of education (72.9% did not receive high school education), high prevalence of previous or current smoking (32.9%), low prevalence of alcohol drinking (11%) and sedentary time <8 h (30.3%). The difference in demographic variables between participants who were included and excluded is shown in Supplementary Table S1. The participants who were included in the final analyses were slightly younger, had higher proportion of females and higher education.

Compared to participants who did not have MetS, those with MetS had a higher prevalence of sedentary time >11 h (21.0% in those with MetS and 10.7 in those without MetS); participants with MetS were older, had more male, had a lower level of education, a higher prevalence of smoking and alcohol drinking, and less physical activity. In addition, participants with MetS had much higher BMI and larger waist circumference, higher levels of diastolic and systolic blood pressure, fasting blood pressure, triglycerides, total cholesterol and low-density lipoprotein, compared to those without MetS.

Association between sedentary time and MetS in Chinese Tibetans

Table 2 demonstrates the association between sedentary time and the prevalence of MetS in crude, age and sex adjusted, and fully adjusted models. Compared to participants who had <8 h of sedentary time, we observed significant positive associations of sedentary time over 11 h per day with the prevalence of MetS in crude (OR: 1.23; 95% CI: 1.12–1.36), age and sex adjusted (OR: 1.18; 95% CI: 1.08–1.29), and fully adjusted (OR: 1.17; 95%

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TABLE 1 Characteristics of the overall study participants and by metabolic syndrome.

Characteristics	Overall participants ($N = 971$)	Metabolic syndrome (MetS)		
		No ($N = 652$, 67.1%)	Yes ($N = 319$, 32.9%)	*p*-value
Sedentary time: *n* (%), hours per day				<0.001
<8	294 (30.3)	212 (32.5)	82 (25.7)	
8–9	402 (41.4)	277 (42.5)	125 (39.2)	
10–11	138 (14.2)	93 (14.3)	45 (14.1)	
>11	137 (14.1)	70 (10.7)	67 (21.0)	<0.001
Age: mean (SD), years	41.1 (13.5)	37.6 (12.0)	48.1 (13.8)	<0.001
Sex: *n* (%)				0.002
Male	254 (26.2)	150 (23.0)	104 (32.6)	
Female	717 (73.8)	502 (77.0)	215 (67.4)	
Education level: *n* (%)				<0.001
College or above	65 (6.7)	50 (7.7)	15 (4.7)	
High school or equivalent	198 (20.4)	132 (20.2)	66 (20.7)	
Less than high school	708 (72.9)	470 (72.1)	238 (74.6)	
Smoking: *n* (%)				<0.001
Never	564 (58.1)	424 (65.0)	140 (43.9)	
Previous or current	407 (41.9)	228 (35.0)	179 (56.1)	
Drinking: *n* (%)				0.002
Never	864 (89.0)	595 (91.3)	269 (84.3)	
Previous or current	107 (11.0)	57 (8.7)	50 (15.7)	
Physical activity: *n* (%)				<0.001
Yes	652 (67.1)	452 (69.4)	200 (62.7)	
No	319 (32.9)	200 (30.6)	119 (37.3)	
BMI: mean (SD), kg/m^2	24.5 (5.4)	23.1 (4.9)	27.3 (5.2)	<0.001
Waist circumference: mean (SD), cm	84.3 (10.2)	81.3 (9.7)	94.1 (11.1)	<0.001
SBP: mean (SD), mmHg	120.7 (18.0)	113.8 (13.5)	134.9 (17.7)	<0.001
DBP: mean (SD), mmHg	78.1 (12.7)	73.6 (9.8)	87.3 (12.9)	<0.001
Fasting blood glucose: mean (SD), mmol/L	5.3 (1.5)	4.9 (1.3)	6.2 (1.7)	<0.001
Triglycerides: mean (SD), mmol/L	1.4 (0.9)	1.2 (0.6)	1.9(1.3)	0.010
Total cholesterol: mean (SD), mmol/L	5.0 (2.3)	4.8 (2.6)	5.4 (1.0)	<0.001
HDL- cholesterol: mean (SD), mmol/L	1.4 (0.4)	1.4 (0.4)	1.5 (0.4)	0.34
LDL- cholesterol: mean (SD), mmol/L	2.9 (0.9)	2.8 (1.0)	3.1 (1.1)	<0.001

BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SBP, systolic blood pressure; SD, standard deviation.

CI: 1.08–1.29) models. The p for nonlinear trend statistics were all significant, indicating the associations between sedentary time and MetS were not linear. This was supported by the much smaller OR estimates and nonsignificant *p*-values for sedentary time categories of 8–9 and 10–11 h per day.

Associations between sedentary time and MetS by age and sex

The associations between sedentary time and the prevalence of MetS by age group and sex are shown in Table 3. We can still observe a consistent pattern of sedentary time > 11 h per day having the largest effect sizes in different sex and age groups. Sedentary time > 11 h per day were statistically significant among female (OR: 1.19; 95% CI: 1.08–1.31), age < 40 (OR: 1.13; 95% CI: 1.01, 1.27), and age ≥40 (OR: 1.20; 95% CI: 1.06–1.37) groups, but insignificant among male group, likely due to the small sample size ($N = 254$) in this group. The magnitude of association between sedentary time > 11 h per day and MetS was slightly stronger in female than in male and in age ≥40 than in age <40, but the *p*-values for interaction tests were insignificant.

Sensitivity analyses

To test the robustness of the findings on the association between sedentary time and MetS at specific MetS

TABLE 2 Association between sedentary time and metabolic syndrome in 971 Tibetans in Garze Tibetan Autonomous Prefecture, Sichuan province, China.

Sedentary time (hours per day)	Crude model		Basic model†		Fully adjusted model‡	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
<8	1 (ref.)	-	1 (ref.)	-	1 (ref.)	-
8–9	1.03 (0.96, 1.11)	0.370	1.03 (0.97, 1.10)	0.325	1.04 (0.98, 1.11)	0.192
10–11	1.04 (0.95, 1.15)	0.327	1.03 (0.94, 1.13)	0.491	1.02 (0.93, 1.11)	0.669
>11	1.23 (1.12, 1.36)	<0.001	1.18 (1.08, 1.29)	<0.001	1.17 (1.08, 1.29)	<0.001
P-values for nonlinear trend		<0.001		<0.001		<0.001

OR, odds ratio.
† The basic model adjusted for age and sex.
‡ The fully adjusted model adjusted for age, sex education, smoking status, drinking status, and BMI.

TABLE 3 Association between sedentary time and metabolic syndrome by sex and age group in 971 Tibetans in Garze Tibetan Autonomous Prefecture, Sichuan province, China.

Sedentary time (hours/d)	OR (95% CI)		*P* for interaction	OR (95% CI)		*P* for interaction
	Male ($n = 254$)	Female ($n = 717$)		Age < 40 ($n = 476$)	Age ≥ 40 ($n = 495$)	
<8	1 (ref.)	1 (ref.)	0.55	1 (ref.)	1 (ref.)	0.71
8–10	1.01 (0.92, 1.12)	1.02 (0.85, 1.22)		1.04 (0.97, 1.14)	1.03 (0.94, 1.15)	
10–11	1.04 (0.97, 1.12)	1.05 (0.92, 1.20)		1.02 (0.91, 1.15)	1.01 (0.89, 1.15)	
>11	1.12 (0.93, 1.35)	1.19 (1.08, 1.31)		1.13 (1.01, 1.27)	1.20 (1.06, 1.37)	

measurements, we further constructed logistic regression models for the five metrics of MetS (Table 4). We found that sedentary time >11 h were significantly associated with increased risk of abdominal obesity (OR: 1.11, 95% CI: 1.01–1.21), triglycerides (OR: 1.14, 95% CI: 1.03–1.25), HDL-C (OR: 1.18, 95% CI: 1.08–1.29), and hyperglycemia (OR: 1.15, 95% CI: 1.01–1.29), while the association was not significant for hypertension (OR: 1.06, 95% CI: 0.97–1.16). Overall, the trend of positive association between sedentary time >11 h and MetS was consistent at different metrics of MetS.

Discussion

In this large cross-sectional study of 971 participants in Garze Tibetan Autonomous Prefecture of Sichuan, China, 319 (32.9%) were diagnosed as having MetS, and we found that sedentary time > 11 h per day were associated with 17% (95% CI: 8–29%) increase in the odds of MetS, compared to those with sedentary time < 8 h per day. The findings were consistent across age and sex groups. To our knowledge, this is the first study that investigates the relationship between sedentary time and MetS among Chinese Tibetans, who reside in rural western China at high altitudes, live in poverty, and hold longer ritual sedentary time influenced by their religious practice.

With the rapid economic development in the last 30 years, China has witnessed substantial social, behavior, lifestyle, and environmental transitions, which lead to a drastic surge in the prevalence of obesity and associated metabolic disorders (22). Although China's national "dynamic zero COVID-19" policy since 2020 has effectively and dramatically reduced the transmission and mortality of COVID-19 (23–25), obesity, mental health, and stagnation of economic growth caused by lockdown, segregation, and mass nucleic acid testing are projected to have substantial synergistic effects on the prevalence of MetS and associated health consequences in Chinese citizens (26–28), including Chinese Tibetans. Although this is a cross-sectional study that could not infer direct causal effects of sedentary time on MetS, but it appears that long sedentary time over 11 h per day is a significant predictor of MetS among Chinese Tibetans, which suggests that reducing sedentary time may help alleviate the burden of MetS among this vulnerable group.

There are a few investigations on the association between sedentary time and metabolic syndrome in China and in other countries. For example, the Nantong Metabolic Syndrome Study reported that 21.6% participant had MetS, and vigorous physical activity was associated with 15–40% decreased odds of metabolic syndrome (29). Another nationwide study of 4,865 adults from the China Health and Nutrition Surveys reported

TABLE 4 Association between sedentary time and components of metabolic syndrome in 971 Tibetans in Garze Tibetan Autonomous Prefecture, Sichuan province, China.

Sedentary time (hours per day)	OR (95% CI)				
	Abdominal obesity[a]	Triglycerides[b]	HDL-C[c]	Hypertension[d]	Hyperglycemia[e]
<8	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
8–9	1.01 (0.94, 1.08)	1.01 (0.96, 1.07)	1.03 (0.97, 1.10)	0.97 (0.89, 1.06)	0.98 (0.96, 1.01)
10–11	1.03 (0.94, 1.13)	1.01 (0.94, 1.09)	1.03 (0.94, 1.13)	1.03 (0.96, 1.10)	1.02 (0.93, 1.11)
>11	1.11 (1.01, 1.21)	1.14 (1.03, 1.25)	1.18 (1.08, 1.29)	1.06 (0.97, 1.16)	1.15 (1.01, 1.29)

[a]Waist circumference ≥85 cm for male or ≥80 cm for female.
[b]Triglycerides ≥ 1.7 mmol/L.
[c]HDL-C < 1.03 mmol/L for male or < 1.29 mmol/L in female.
[d]SBP ≥130 mmHg or DBP ≥ 85 mmHg.
[e]Fasting glucose ≥ 5.6 mmol/L.

that sedentary time was associated with significantly higher risk of MetS (OR: 1.3; 95% CI: 1.1–1.6) (30). An earlier meta-analysis reviewed 10 cross-sectional studies (n = 21,393) reported that more sedentary time was associated with an increased odds of MetS (OR 1.73, 95% CI 1.55–1.94) (31). Compared to these previous investigations, our study reported consistently positive association but with a lower OR (OR: 1.17; 95% CI: 1.08–1.29). More importantly, our study filled in a knowledge gap of the relationship between sedentary behavior and MetS among Tibetans in China, and the results have policy implications on health equity.

Although our data were collected from a Tibetan-dominant prefecture in Southwest China, several findings are consistent with those in other studies conducted in different areas, which corroborates the validity of our findings. The MetS prevalence of 32.9% in this study is similar to the results of a study among a group older Tibetans in Jiarong (Northwest Sichuan Province) using similar diagnosis criteria, which reported the MetS prevalence of 37.6% (20). Other studies using the China Multi-Ethnic Cohort reported the prevalence of MetS of 17.8% among Tibetans while 11.9% among both Tibetans and Han Chinese using a stricter National Cholesterol Education Program Adult Treatment Panel III (ATP III) criteria (32, 33). The difference in prevalence rate of MetS among Tibetans and a mixture of Han Chinese also reveals the higher prevalence of MetS in minority group Tibetans than the dominate group Han Chinese, suggesting further policy actions to improve health equity in Chinese minority ethnicity groups residing in remote rural areas (34).

Our study has several limitations. First, our study site includes only one prefecture in Sichuan, China, which limits the generalizability of findings to Tibetans in other parts of China. Second, our regression models included a limited set of covariates due to limited data accessibility and quality, which may lead to potential missing covariate bias in our findings. Third, this is a cross-sectional survey that lacks imposed treatment or intervention, which refrains from making causal claims about the relationship between sedentary time and MetS. Fourth, there are several definitions for MetS including those made by the World Health Organization in 1999, National Cholesterol Education Program ATP3 in 2005, and the one by the International Diabetes Federation in 2006 (used in our study); there is not yet consensus on the best definition of MetS, and the uncertainty in MetS definition may cause outcome misclassification and heterogeneity of results across studies. Fifth, sedentary time was collected as category variable and the cutoffs were somewhat arbitrary, and we were not able to construct exposure-response curves in the results.

Nonetheless, this is the first study that investigate the relationship between sedentary time and MetS among Chinese Tibetans. Our study recruited a relatively large sample of about 1,000 middle-aged Tibetan participants using a multi-stage, stratified, random-cluster sampling strategy, and collected a set of variables involving demographics, behavior, and laboratory tests. The findings fill the knowledge gap on the magnitude of association between sedentary time and MetS among Chinese Tibetans, suggesting local efforts to educate Tibetans to boost physical activity and reduce sedentary time to reduce the prevalence of MetS, as well as the resulting cardiovascular health outcomes.

Conclusions

In this large cross-sectional survey of Chinese Tibetans in Sichuan Province, around one third of the participants manifest evidence of MetS, showing high burden of MetS among Chinese Tibetans. Sedentary time longer than 11 h per day is significantly associated with increased risk of MetS. The findings suggest that efforts on health education may alleviate the health burden of MetS among Tibetans in China.

Data availability statement

The datasets presented in this article are not readily available because please contact author for data requests. Requests to access the datasets should be directed to QZ, zhangqsh@gd2h.org.cn.

Ethics statement

This study was approved by the Ethics Committee of Guangdong Second Provincial General Hospital (20201229-KJBF-02-01). All of the participants in this study signed an informed consent form.

Author contributions

LG: conceptualization, investigation, visualization, writing—original draft, and writing—reviewing and editing. YL: investigation, visualization, writing—original draft, and writing—reviewing and editing. TX, LL, YN, YY, and QL: investigation. QZ: investigation, visualization, and supervision. All authors contributed to the article and approved the submitted version.

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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.2022.1009764/full#supplementary-material

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EDITED BY
Yihui Du,
University Medical Center Groningen, Netherlands

REVIEWED BY
Muna Ahmead,
Al-Quds University, Palestine
Alexandre Sizilio,
Faculdade Israelita de Ciências da Saúde Albert Einstein Hospital Israelita Albert Einstein, Brazil
Ashten Duncan,
University of New Mexico Health Sciences Center, United States
Marcin Siwek,
Jagiellonian University, Poland

*CORRESPONDENCE
Deliang Wen
dlwen@cmu.edu.cn

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The mediating role of general academic emotions in burnout and procrastination among Chinese medical undergraduates during the COVID-19 pandemic: A cross-sectional study

Ruoyi Qu[1], Ning Ding[1], Honghe Li[1], Xinzhi Song[1], Zhangzhao Cong[2], Ruoxin Cai[3], Yaxin Zhu[1] and Deliang Wen[1]*

[1]Institute for International Health Professions Education and Research, China Medical University, Shenyang, China, [2]Department of Teaching Affairs, China Medical University, Shenyang, China, [3]The First Clinical Department, China Medical University, Shenyang, China

Background: Academic procrastination has become more prevalent during the COVID-19 pandemic due to teaching/learning changes. This phenomenon induces academic burnout, which is already serious among medical students. However, the academic emotion, which is the factor most vulnerable to changes in the academic environment, is still unknown. Therefore, the current study aimed to investigate the mediating role of general academic emotions in procrastination and burnout among Chinese medical students during the COVID-19 pandemic.

Methods: This cross-sectional study enrolled 995 medical students from China Medical University. We applied the Chinese version of the Maslach Burnout Inventory Student Survey (MBI-SS), the Aitken Procrastination Inventory (API) and the General Academic Emotion Questionnaire for College Students (GAEQ) to evaluate the variables of interest. We examined the mediation effects of GAEs by hierarchical linear regression analysis.

Results: Correlation analyses showed a significant positive correlation between procrastination and burnout. Procrastination and burnout positively and negatively correlated with negative academic emotions, respectively. Hierarchical linear regression analyses showed that procrastination had positive associations with negative academic emotions, while it had negative associations with positive academic emotions. The contributions (as mediators) of GAEs to burnout and procrastination were 21.16% (NAEs), 29.75% (PAEs), 54.25% (NDEs) and 23.69% (PDEs).

Conclusions: The results indicate that academic emotions had mediating effects on procrastination and burnout. Medical students' worries about the uncertainty of the learning environment may have exacerbated

academic burnout. Targeted improvements in the teaching environment to communicate encouragement and reduce anxiety and helplessness among medical undergraduates for implementing medical education while preventing and controlling the infection.

KEYWORDS

COVID-19, general academic emotions, burnout, procrastination, medical undergraduates

Introduction

Due to travel limitations and closures of medical schools and universities, online learning ("zero contact") has rapidly been accepted as the "new normal" (1–3) and has played a positive role in formal medical teaching/learning (4–6) worldwide during the coronavirus disease 2019 (COVID-19) pandemic. However, the virtual learning environment involves no actual interpersonal interactions, which has worsened existing challenges and created new barriers between students and teachers, especially psychological ones, such as variance in academic motivation, undetectable procrastination and reduced opportunity for psychological interventions (7–9). Therefore, identifying psychological risk factors is important to improve satisfaction with online teaching/learning (10).

Burnout is generally conceptualized as a prolonged response to chronic emotional and interpersonal workplace stress (11) and has three core dimensions: emotional exhaustion, cynicism (also referred to as depersonalization) and increasing feelings of inefficacy (12). The demand-control theory of Robert Karasek (13) explains the balance between psychological demands and available resources. Excessive labor or tense relationships may lead to low engagement and well-being, as well as suicidal tendencies (14), which explains the vulnerability to burnout among health professionals and medical undergraduates (15–17). According to a global meta-analysis of 17,431 medical students in 24 studies, the total burnout prevalence was estimated to be 44.2%, which is even higher than among residents (18). Emotional exhaustion was the most prevalent symptom (40.8%); depression, anxiety, suicidality and other emotional disturbances were also associated with burnout (19–21). Especially in the context of the COVID-19 pandemic, lack of family support caused by isolation, the extension of time spent on degree and suppressed enthusiasm for offline learning are all contributors to burnout among medical students (22, 23). A quantitative study with 741 training medical students from six U.S. medical schools suggested that, 74.7% of the participants agreed that COVID-19 had a great impact on their medical education, and 61.3% of the respondents were even willing to take the risk of illness to offset the burnout caused by the change of clinical activities (24). Although studies have focused on the impact of COVID-19 on the mental health of medical students (25), but there is still insufficient evidence to analyze influential factors and giving a better policy to relieve the anxiety emotions.

Extending previous studies (26), Steel (27) defined procrastination as "*the voluntary delay of an intended and necessary and/or [personally] important activity, despite expecting potential negative consequences that outweigh the positive consequences of the delay.*" Previous studies found that procrastinating prevalence among university students was double or triple that of the general population (28–30). Regarding medical professionals and undergraduates, similar to the burnout phenomenon mentioned above, procrastination, i.e., the needless delay of things that one intends to do, is also a major risk factor for low well-being (31). Evidence suggests that procrastination is positively correlated with academic anxiety (32), distress (33) and low motivation in students (34), resulting in more agitation before a test or poor academic performance across the entire semester. Besides the psychological aspects, a correlation between procrastination and the academic environment has also been demonstrated among medical students (35–37). Heavy dependency on the internet and lax time management may significantly contribute to the Internet or smartphone addiction (38, 39) during COVID-19 quarantine. This may exacerbate low well-being and increase the possibility of emotional disorders caused by procrastination (40). Although burnout and procrastination among medical students are positively correlated with adverse emotional factors and poor emotional management, few studies have discussed the relationship between burnout and procrastination.

General academic emotions (GAEs) have also been suggested to play a role in satisfaction with the learning environment and academic performance in medical campus (41–43). Pekrun's control-value theory (44) explained that subjective control over activities and their outcomes, as well as subjective appraisals of these activities and outcomes, are relevant to academic emotions. Desire and a clear expectation of success promote positive academic emotions and facilitate

Abbreviations: CI, confidence interval; CMU, China Medical University; GAEs, general academic emotions; NAEs, negative activating emotions; NDEs, negative deactivating emotions; OR, odds ratio; PAEs, positive activating emotions; PDEs, positive deactivating emotions; SD, standard deviation.

the self-discipline required to achieve good outcomes. Likewise, unavoidable failure or a lack of internal control result in negative academic emotions. Against the backdrop of the COVID-19 pandemic, online learning, lockdown of hospitals, inability to perform actual operations and many other major changes were unprecedented challenges to the provision of medical education (45). In the process of adapting to these changes involving peer interactions and learning evaluations, medical undergraduates are facing much uncertainty, which may disrupt academic emotions and achievement (46, 47).

In that case, we hypothesize that: (1) Procrastination is positively correlated with burnout among medical undergraduates based on their relationships with emotional factors and (2) GAEs play mediating roles in the relationship between burnout and procrastination among Chinese medical undergraduates. We assessed the association between burnout and procrastination among Chinese medical undergraduates studying at home during the COVID-19 pandemic, and the mediating effects of GAEs in the association of burnout with procrastination (after adjusting for the demographic variables and online learning preferences). Looking forward to addressing the concerns mentioned above and discovering the intervention targeted to improve mental health of medical undergraduates during the COVID-19 pandemic.

Methods

Study design and procedure

The Human Research Ethics Committee of China Medical University approved our study. All participants were familiarized with the study protocol before signing the consent form, and ethical principles were adhered to during the whole survey process. All information collected from participants was confidential and anonymous. We conducted this cross-sectional study of China Medical University (CMU) from August to September 2020. The questionnaire and consent forms were distributed online by scanning a QR code. In total, 1,045 medical undergraduates who had studied exclusively online in the spring semester during the COVID-19 pandemic voluntarily took part in our survey. Ultimately, 995 undergraduates completed the online questionnaire satisfactorily.

Demographic variables

The medical undergraduates participating in the study were in their first to the fourth year, and were majoring in clinical medicine, preventive medicine, nursing, and medical technology. We collected demographic information including age, gender, and household registration. Online learning duration and preference data were also gathered. We applied the following measuring tools to assess burnout, procrastination and academic emotions.

Measurement of burnout

Burnout among medical undergraduates was assessed using the Chinese version of the Student Burnout Inventory, adapted from the Maslach Burnout Inventory Student Survey (MBI-SS). This self-report scale contains 16 items, scored from one point (*strongly disagree*) to five points (*totally agree*) and classified into three dimensions including exhaustion, cynicism and professional efficacy. The exhaustion dimension consists of four items (items 2, 5, 8, and 12) and reflects fatigue resulting from the study. The cynicism dimension is composed of five items (items 3, 6, 9, 10, 13) and indicates a negative attitude toward studying. The professional efficacy dimension includes seven items (items 1, 4, 7, 11, 14, 15, 16) and is concerned with the sense of personal achievement during learning. The inventory has adequate reliability and validity for measuring Chinese samples (48). The Cronbach's alpha coefficient of our study was 0.876.

Measurement of procrastination

We measured procrastination among medical undergraduates using the Chinese version of the Aitken Procrastination Inventory (API), which is a single- dimension scale including 19 items; item scores range from one point (*strongly disagree*) to five points (*totally agree*). This self-report scale evaluates undergraduates' long-term procrastination. The Chinese version of the API has proven reliability and validity (49). The Cronbach's alpha coefficient in our study was 0.905.

Measurement of GAEs

The General Academic Emotion Questionnaire for College Students (GAEQ) was applied to evaluate academic emotions. The GAEQ is adapted from the Academic Emotion Questionnaire (AEQ) (50) and contains 88 items scored from one point (*strongly disagree*) to five points (*totally agree*). This self-report instrument measures 10 academic emotions including anxiety (15 items), boredom (13 items), relief (10 items), hopelessness (10 items), pride (9 items), shame (7 items), enjoyment (7 items), hope (7 items), anger (5 items) and interest (5 items). Based on the theory of Pekrun (51) and results of exploratory factor analysis, negative activating emotions (NAEs: shame, anxiety, and anger), positive activating emotions (PAEs: interest, enjoyment, and hope), negative deactivating emotions (NDEs: hopelessness and boredom) and positive deactivating emotions (PDEs: pride and relief)

are distinguished. The acceptable reliability and validity of the GAEQ have been proven in Chinese college students (52) and the Cronbach's coefficient in the present study was 0.926.

Statistical analysis

We report continuous variables as means with standard deviation (SD) and categorical variables as frequencies and percentages, based on descriptive analyses. We applied the *t*-test or one-way ANOVA to analyze burnout, procrastination and GAEs according to demographic factors. Pearson correlation analysis was used to identify correlations among burnout, procrastination and GAEs.

Binary logistic regression analysis was applied to assess the impact of GAEs and procrastination on burnout. Participants were divided into high- and low-burnout groups using the mean as the cut-off value. The quartile spacing method was used to categorize participants into degree groups (low, relatively low, relatively high and high), based on their GAEs and procrastination scores, to estimate relationships between burnout and specific components (exhaustion, cynicism and professional efficacy); odds ratios (ORs) and 95% confidence intervals (CIs) were generated.

We examined the mediation effect of GAEs on the relationship between burnout and procrastination by hierarchical linear regression analysis. Procrastination was modeled as an independent variable, while burnout was the dependent variable. The enter and resampling methods were used to assess the mediating role of GAEs. Covariates included demographic variables and online learning preferences. Figure 1 presents the hierarchical linear regression analysis process. We performed bootstrap analysis (53) based on the process of Hayes (version 3.4.1). Five-thousand samples were bias-corrected and 95% CIs were generated for each GAE, to identify significant mediation effects.

All statistical analyses were conducted with SPSS 20.0 for Windows software (SPSS, Inc., Chicago, IL, USA). All tests were two-sided ($\alpha = 0.05$). *P*-values < 0.05 and 95% CIs excluding zero were considered to indicate statistical significance.

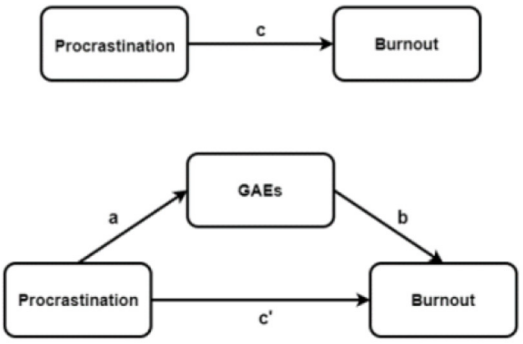

FIGURE 1
Procrastination, Burnout and GAEs in hierarchical linear regression analysis process among Chinese medical undergraduates. a, Association of procrastination with GAEs; b, association of GAEs with burnout; c, direct association between procrastination and burnout; c', association between procrastination and burnout with GAEs as mediators.

TABLE 1 Demographic characteristic of subjects.

Variables		Numbers	Percentage (%)
Gender	male	342	34.37
	female	653	65.63
Household registration	rural	352	35.38
	urban	643	64.62
Academic year	Year 1	461	46.33
	Year 2	365	36.68
	Year 3	115	11.56
	Year 4	54	5.43
Major	clinical medicine	615	61.81
	preventive medicine	251	25.23
	nursing	38	3.82
	medical technology	91	9.14
Equipment	Desktop computer	45	4.52
	Notebook computer	650	65.33
	Tablet computer	99	9.95
	Mobile phone	201	20.20
Online learning	<30 h	142	14.27
time weekly	30–35 h	305	30.65
	36–40 h	275	27.64
	41–45 h	152	15.28
	>46 h	121	12.16

Rigor

We implemented several strategies to ensure the credibility of the results. Suggestions from experts majoring in medical education, social medicine and health management were taken into consideration at the design stage. Knowledgeable colleagues explained the study procedure to the participants before they filled out the questionnaire. All questionnaire items were mandatory, and maximum and minimum completion times were set to guarantee data quality. Participants who responded "totally agree" or "totally disagree" to all items were excluded. Double entry was applied in the data collation stage. A small-scale pre-experiment was performed before the formal investigation; any problems were recorded in detail.

TABLE 2 Results of GAEQ among CMU medical undergraduates under the background of COVID-19.

Variable		NAEs		PAEs		NDEs		PDEs	
	Means ± SD	*P*	Means ± SD	*P*	Means ± SD	*P*	Means ± SD	*P*	
Gender	Male	78.01 ± 21.18	0.059	76.93 ± 13.61	0.986	52.53 ± 20.89	**0.006****	70.32 ± 13.50	**0.006****
	Female	75.56 ± 18.49		75.56 ± 18.49		48.97 ± 15.76		67.98 ± 11.04	
Location	Rural	77.80 ± 18.73	0.095	75.91 ± 12.25	0.060	51.71 ± 17.02	**0.046***	67.63 ± 11.69	**0.025***
	Urban	75.64 ± 19.85		77.47 ± 12.59		49.36 ± 18.11		69.41 ± 12.12	
Grade	Year 1	76.82 ± 20.37	0.734	77.35 ± 12.83	**0.025***	50.33 ± 18.45	0.338	69.55 ± 12.63	0.090
	Year 2	76.32 ± 18.94		77.61 ± 12.08		49.19 ± 17.19		68.72 ± 11.30	
	Year 3	74.62 ± 18.82		74.46 ± 12.57		51.34 ± 17.05		66.62 ± 12.02	
	Year 4	77.24 ± 16.77		73.87 ± 11.23		53.35 ± 16.94		67.28 ± 10.31	
Major	Clinical medicine	76.55 ± 19.53	0.403	77.45 ± 12.36	0.152	49.68 ± 17.77	0.169	69.14 ± 11.94	0.616
	Preventive medicine	76.58 ± 18.92		75.37 ± 12.71		51.67 ± 17.60		68.02 ± 11.76	
	Nursing	79.58 ± 19.63		76.74 ± 12.48		53.76 ± 17.24		69.32 ± 11.77	
	Medical technology	73.62 ± 20.62		77.66 ± 12.60		48.10 ± 18.09		68.26 ± 13.05	
Equipment	Desktop computer	82.53 ± 22.07	**0.036***	77.98 ± 11.65	0.905	54.91 ± 19.16	0.085	69.96 ± 11.08	0.856
	Notebook computer	75.66 ± 18.94		76.92 ± 12.56		49.41 ± 17.03		68.79 ± 11.93	
	Tablet computer	74.44 ± 21.13		77.20 ± 13.11		49.54 ± 19.42		69.09 ± 12.26	
	Mobile phone	78.41 ± 19.47		76.54 ± 12.17		51.99 ± 18.72		68.34 ± 12.32	
Online learning	<30 h	79.53 ± 19.16	0.055	74.39 ± 12.93	**0.006****	54.37 ± 19.00	**0.007****	66.86 ± 13.29	**0.007****
time weekly	30–35 h	77.28 ± 18.89		76.79 ± 12.28		51.09 ± 17.58		68.35 ± 11.57	
	36–40 h	74.60 ± 18.93		77.20 ± 12.56		47.92 ± 16.69		69.27 ± 11.84	
	41–45 h	74.07 ± 17.88		76.45 ± 12.16		48.76 ± 15.62		67.98 ± 10.82	
	>46 h	77.59 ± 23.65		80.18 ± 12.19		50.01 ± 20.64		72.02 ± 11.99	

*$P < 0.05$, **$P < 0.01$; Results were all controlled by the covariates; SD, standard deviations; NAE, negative activating emotions; PAE, positive activating emotions; NDE, negative deactivating emotions; PDE, positive deactivating emotions.
"Bold" mean that the values are statistically significant.

Results

Participant characteristics

In total, 995 medical undergraduates from CMU were included in our survey. The average age of the participants was 19.83 ± 1.15 years and the majority were female (65.63%) and residing in an urban area (64.62%). The undergraduates mostly used notebook computers (65.33%) for online learning and normally spent 30–40 h (58.29%) engaged in distance learning per week. Table 1 shows the detailed demographic characteristics of all participants.

GAEs

There was significant sex difference in terms of the deactivation of academic emotions. Rural undergraduates' scored lower for PDEs than urban undergraduates, who scored higher for NDEs. Junior medical undergraduates scored highly for PAEs. Participants using desktop computers for online learning had the highest NAE scores. Undergraduates with higher PAE scores spent more time distance learning. All of the GAE results are presented in Table 2.

Burnout and procrastination levels

Female undergraduates reported higher total burnout levels than male undergraduates, as well as within the dimensions of exhaustion and cynicism. Undergraduates from rural areas showed higher total burnout levels than urban undergraduates, as well as higher burnout in the exhaustion and professional efficacy domains. Year 1 medical undergraduates experienced less burnout in the professional efficacy domain than undergraduates in other years. Medical undergraduates who spent less time engaged in online learning experienced more burnout.

Rural undergraduates showed higher levels of procrastination. Medical undergraduates who used desktop computers procrastinated the most during the COVID-19 pandemic. The level of procrastination of participants studying for < 30 h per week was significantly different from that of the other participants. Supplementary Tables S1, S2 show the results in detail.

TABLE 3 Means, SD and correlations of continuous variables.

Variables	Means	SD	1	2	3	4	5	6
1. Procrastination	42.27	12.19	1					
2. Burnout	34.63	9.52	**0.708*****	1				
3. NAEs	76.41	19.48	**0.519*****	**0.573*****	1			
4. PAEs	76.92	12.49	**-0.566*****	**-0.637*****	**-0.249*****	1		
5. NDEs	50.19	17.76	**0.690*****	**0.778*****	**0.775*****	**-0.556*****	1	
6. PDEs	68.78	11.99	**-0.531*****	**-0.598*****	**-0.372*****	**0.836*****	**-0.476*****	1

***$P < 0.001$; SD, standard deviations; Results were all controlled by the covariates; NAE, negative activating emotions; PAE, positive activating emotions; NDE, negative deactivating emotions; PDE, positive deactivating emotions.
"Bold" mean that the values are statistically significant.

Relationships among burnout, procrastination and GAEs

Correlations among burnout, procrastination and GAEs are shown in Table 3. There was a significant positive correlation between procrastination and burnout among the CMU after adjusting for age, major, online learning equipment and all other covariates. Procrastination and burnout positively and negatively correlated with negative academic emotions, respectively.

The associations of burnout and its components with procrastination and GAEs are presented in Table 4. Binary logistic regression showed that burnout and its components significantly decreased with an increase of positive academic emotions and procrastination, and increased with higher levels of negative academic emotions.

Mediating roles of GAEs

Table 5 shows the mediating effects of GAEs. Procrastination had positive associations with NAEs and NDEs, and negative associations with PAEs and PDEs (path **a**). NAEs and NDEs positively correlated with burnout, while PAEs and PDEs showed the opposite correlation (path **b**). When procrastination and GAEs were simultaneously entered into the regression model, NAEs (95% CI: 0.092–0.142), PAEs (95% CI: 0.121–0.195), NDEs (95% CI: 0.261–0.342) and PDEs (95% CI: 0.095–0.166) mediated the direct effects (0.553–0.436, 0.394, 0.300 and 0.131 respectively, after adjusting for all covariates (path **c'**). The contributions (as mediators) of GAEs to burnout and procrastination (path **c**) were 21.16% (NAEs), 29.75% (PAEs), 54.25% (NDEs) and 23.69% (PDEs).

Discussion

In today's unprecedented COVID-19 pandemic era, quarantine measures, which have been used effectively for centuries to slow the transmission of infection, have been implemented worldwide. Due to the high concentration of students and frequent social activities on campus, universities around the world have closed campuses and implemented online curricula and digital learning (54). Lockdown, isolation and social distancing effectively controlled the epidemic, but have had a detrimental impact on students' mental health (especially on medical undergraduates whose major emphasizes practice) (55). In the present study, we first discussed the positive correlation between procrastination and burnout and demonstrated mediating effects of GAEs. The mediating effect of NDEs was the most significant among all GAEs; due to the significant change in the learning environment, medical undergraduates' procrastination led to more serious burnout in association with major uncertainties and anxiety. In turn, this may undermine academic performance and psychological health. We also found that gender, location, online learning duration and equipment preferences, and academic year were associated with mental health and GAEs.

The prevalence of burnout differs by gender among medical professions (56). Female medical professionals suggested suffer more from burnout, due to discriminative behavior from patients, occupational biases or gendered macro-aggressions (57–59). However, an investigation assessing the frequency of psychological distress among physician residents showed that, whereas female residents were more likely to suffer from anxiety and depression, male residents were more vulnerable to burnout (60). It seems that, during training and earlier career stages, male medical undergraduates may suffer more from burnout, which were similar to the result of present study. The question is, why female medical professionals suffer more from burnout later in their careers? Whether burnout among female medical professionals should be labeled as a "workplace" or "occupational" characteristic also merits further study (61, 62). Regarding the influence of switching to the online learning environment, we found that rural medical undergraduates reported higher burnout and procrastination levels. This might be related to online learning equipment proficiency and quality, barriers to accessing learning resources,

TABLE 4 The relations of burnout, delay and GAEs by using binary logistic regressions.

Variables		Burnout OR (95%CI)	Exhaustion OR (95%CI)	Cynicism OR (95%CI)	Professional efficacy OR (95%CI)
NAEs	Low (ref.)	1.00	1.00	1.00	1.00
	Relatively low	5.04*** (3.125, 8.131)	3.48*** (2.151, 5.643)	4.86*** (3.017, 7.838)	3.71*** (2.508, 5.476)
	Relatively high	18.86*** (11.517, 30.893)	15.66*** (9.271, 25.463)	11.03*** (6.828, 17.811)	7.13*** (4.729, 10.762)
	High	19.01*** (11.679, 30.938)	22.28*** (13.640, 36.397)	11.48*** (7.141, 11.456)	4.49*** (3.041, 6.639)
PAEs	Low (ref.)	1.00	1.00	1.00	1.00
	Relatively low	0.19*** (0.112, 0.325)	0.34*** (0.222, 0.514)	0.29*** (0.192, 0.449)	0.42*** (0.247, 0.708)
	Relatively high	0.50*** (0.030, 0.083)	0.18*** (0.122, 0.270)	0.11*** (0.073, 0.166)	0.12*** (0.075, 0.192)
	High	0.12*** (0.007, 0.022)	0.06*** (0.039, 0.096)	0.05*** (0.028, 0.073)	0.01*** (0.006, 0.020)
NDEs	Low (ref.)	1.00	1.00	1.00	1.00
	Relatively low	8.94*** (4.423, 18.055)	3.66*** (2.108, 6.353)	6.77*** (3.504, 13.095)	6.28*** (4.058, 9.707)
	Relatively high	58.95*** (29.251, 118.810)	20.50*** (11.991,35.037)	25.23*** (13.262,48.015)	13.04*** (8.338, 20.380)
	High	218.35*** (101.984, 467.506)	83.33*** (45.752, 151.787)	104.62*** (53.028, 206.415)	15.82*** (10.025, 24.965)
PDEs	Low (ref.)	1.00	1.00	1.00	1.00
	Relatively low	0.23*** (0.143, 0.384)	0.50*** (0.336, 0.750)	0.35*** (0.236, 0.521)	0.41*** (0.239, 0.703)
	Relatively high	0.06*** (0.037, 0.100)	0.21*** (0.137, 0.311)	0.17*** (0.112, 0.255)	0.08*** (0.050, 0.141)
	High	0.02*** (0.010, 0.031)	0.02*** (0.046, 0.114)	0.08*** (0.050, 0.124)	0.01*** (0.004, 0.016)
Procrastination	Low (ref.)	1.00	1.00	1.00	1.00
	Relatively low	5.22*** (2.998, 9.103)	3.47*** (2.120, 5.658)	4.09*** (2.297, 7.264)	5.23*** (3.383, 8.075)
	Relatively high	21.47*** (12.468, 36.964)	9.86*** (6.148, 15.809)	14.53*** (8.392, 25.159)	12.58*** (8.097, 19.558)
	High	85.11*** (46.283,156.523)	44.56*** (26.112, 76.038)	60.87*** (33.660, 110.093)	15.18*** (9.639, 23.911)

***$P < 0.001$; Results were all controlled by the covariates; SD, standard deviations; GAEs, general academic emotions; NAEs, negative activating emotions; PAEs, positive activating emotions; NDEs, negative deactivating emotions; PDEs, positive deactivating emotions.

TABLE 5 The mediating role of GAEs on the associations between procrastination and burnout.

Mediators	c	a	b	c'	Mediation (a*b)	95%CI
NAEs	0.553***	0.848***	0.138***	0.436***	0.117*	0.092–0.142
PAEs	0.553***	−0.594***	−0.268***	0.394***	0.159*	0.121–0.195
NDEs	0.553***	1.012***	0.297***	0.253***	0.300*	0.261–0.342
PDEs	0.553***	−0.247***	−0.532***	0.422***	0.131*	0.095–0.166

*$P < 0.05$, ***$P < 0.001$; Results were all controlled by the covariates; SD, standard deviations; GAEs, general academic emotions; NAEs, negative activating emotions; PAEs, positive activating emotions; NDEs, negative deactivating emotions; PDEs, positive deactivating emotions. a, associations of procrastination with GAEs; b, associations of GAEs with burnout; c', association between procrastination and burnout after adding GAEs as mediators; 95%CI were calculated by bootstrap method.

and interference with learning by anxiety regarding peer competition. Furthermore, medical undergraduates who spent < 30 h studying online per week had higher levels of burnout and procrastination. Medical undergraduates who devoted less time to learning online were more likely to have psychological problems related to a lack of self-control, uncertainty regarding learning goals and anxiety about quarantine. In addition, desktop learning appeared to cause the highest level of procrastination, such that medical undergraduates preferred using mobile devices to study during the pandemic.

Lockdown, quarantine measures and social distancing have had detrimental effects on the mental health of medical undergraduates, leading to dramatically increased levels of depression, anxiety and stress (63, 64). We also found positive correlations of burnout with procrastination and negative learning-related emotions. Moreover, NDEs showed the highest correlations with burnout and procrastination among all academic emotions, indicating that the medical undergraduates felt confusion and helplessness when trying to learn during the pandemic. In terms of deactivating emotions, female undergraduates and those from rural areas felt more helpless and scared than urban undergraduates. Pekrun pointed out that academic emotions encompass all emotional experiences that a person may experience during the life course (44). Medical undergraduates are already under high academic

and social pressure, which can cause procrastination (32). Major events, such as the COVID-19 pandemic, might trigger learning anxiety, boredom in association with homework, loss of interest in learning or no expectation of success in examinations, or even professional identity and professionalism among medical undergraduates.

We studied the mediating role of academic emotions and confirmed our hypothesis, i.e., that academic emotions suggested mediating effects with respect to procrastination and anxiety. PAEs and PDEs reduced the correlation between procrastination and burnout by 28.75 and 23.69% respectively. Thus, the mediating role of PAEs was greater than that of PDEs. NDEs explained 54.25% of the mediating effect, which was not only higher than that explained by NAEs (21.16%), but also higher than all other GAEs. This indicated that medical undergraduates' worries about uncertainties of the learning environment, including pessimism about their academic prospects and low interest in learning, were most prominent when engaged in distance learning in the context of the COVID-19 pandemic. According to Pekrun (44), NDEs reflect undergraduates' uncertainty about outcomes, loss of control, and feelings of powerlessness regarding the learning process associated with increased telecommunication, perceptual barriers, and a lack of self-regulation or external regulation of learning (46, 50). In addition to further verifying Pekrun's theory, we also found that, as negative emotions heightened, the overall risk of burnout increased. Thus, without timely intervention, negative academic emotions might exacerbate academic burnout.

There were several limitations to the present study. The participants were all from CMU, which might reduce the representativeness and generalizability of our results. Also, the results may have been affected by recall bias and survey-driven self-selection bias. Other potential factors, such as high homework loads, challenging exams, lack of role models may also contribute to medical undergraduates' stress and procrastination, that were worthy of further discussion. Analysis of pre-epidemic data would have enhanced the usefulness of our study, along with follow-up. Balancing pandemic prevention measures with the protection of medical undergraduates' physical and mental health is an urgent issue. The present study provides empirical evidence regarding how to identify targets for, and formulate, intervention strategies for Chinese medical undergraduates while simultaneously preventing the spread of COVID-19.

Conclusions

In summary, the current results highlighted the correlation between burnout and procrastination with the mediating role of general academic emotions among medical undergraduates. In the context of COVID-19, this study profoundly identified the emotional maladjustment and confusion of medical undergraduates in response to changes in their learning environment. Our findings provide a practical basis for further accurate optimization of online teaching environment, improvement of teaching evaluation methods, promotion of medical undergraduates' anxiety, stress and depression management, in terms of improving mental health of medical undergraduates.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number (s) can be found in the article/Supplementary material.

Ethics statement

The studies involving human participants were reviewed and approved by the Human Research Ethics Committee of China Medical University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

ND and DW substantially contributed to the conception and design of the research. ZC contributed to recruit volunteers and RC helped with the data acquisition. RQ analyzed the data, interpreted the results, and prepared the initial draft of the manuscript. The double check with the dataset was carried out by XS. ND, HL, and YZ critically reviewed the manuscript and gave advice for modifications. HL, ND, and DW worked for the final approval of the version of the manuscript to be published. All authors contributed to the article and approved this submitted version.

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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.2022.1011801/full#supplementary-material

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EDITED BY
Hubing Shi,
Sichuan University, China

REVIEWED BY
Xiaomin Song,
BeiGene, China
Elena Stanculescu,
University of Bucharest, Romania

*CORRESPONDENCE
Sam S. S. Lau
samlau@hkbu.edu.hk

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Assessing COVID-19-related health literacy and associated factors among school teachers in Hong Kong, China

Sam S. S. Lau[1,2,3,4]*, Eric N. Y. Shum[1], Jackie O. T. Man[1,3], Ethan T. H. Cheung[1,3], Padmore Adusei Amoah[5], Angela Y. M. Leung[6], Kevin Dadaczynski[7,8] and Orkan Okan[9]

[1]Research Centre for Environment and Human Health, School of Continuing Education, Hong Kong Baptist University, Kowloon, Hong Kong SAR, China, [2]College of International Education, Hong Kong Baptist University, Kowloon, Hong Kong SAR, China, [3]Multidisciplinary Research Centre, School of Continuing Education, Hong Kong Baptist University, Kowloon, Hong Kong SAR, China, [4]Institute of Bioresource and Agriculture, Hong Kong Baptist University, Kowloon, Hong Kong SAR, China, [5]Department of Applied Psychology, School of Graduate Studies, Institute of Policy Studies, Lingnan University, Tuen Mun, China, [6]School of Nursing, Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China, [7]Public Health Centre Fulda, Fulda University of Applied Sciences, Fulda, Germany, [8]Center for Applied Health Science, Leuphana University Lueneburg, Lueneburg, Germany, [9]Department of Sport and Health Sciences, Technical University Munich, Munich, Germany

Objectives: The coronavirus disease 2019 (COVID-19) pandemic developed rapidly, with changing guidelines, misinformation, inaccurate health information and rumors. This situation has highlighted the importance of health literacy, especially among educators. The aims of this study were (i) to assess COVID-19-specific health literacy among school teachers in Hong Kong and (ii) to examine its association with demographic factors, self-endangering work behaviors (i.e., work intensification, work extensification and work quality reduction), secondary burnout symptoms (i.e., exhaustion related to work and psychosomatic complaints), the level of knowledge of COVID-19- or pandemic-related information and the level of confusion about COVID-19-related information.

Methods: A self-report survey was administered to 366 Hong Kong school teachers from April 2021 to February 2022. COVID-19-specific health literacy was measured using the HLS-COVID-Q22 instrument. Other instruments, including self-endangering work behavior scales (i.e., extensification of work, intensification of work and work quality reduction) and two dimensions of the Burnout Assessment Tool (i.e., psychosomatic complaints and exhaustion) were also used for assessment. Data were analyzed using an independent samples Student's *t*-test, analysis of variance, correlation analysis and adjusted multilinear regression models.

Results: The results showed that 50.8% of school teachers had sufficient health literacy, 38.3% had problematic health literacy and 10.9% had inadequate health literacy. The HLS-COVID score did not vary by sex, but varied according to the type of school, the number of working hours per week and the number of students attending the school. Teachers with sufficient health literacy

scored significantly lower for two types of self-endangering work behavior–intensification of work ($p = 0.003$) and work quality reduction ($p = 0.007$)—than those with insufficient health literacy. After excluding those who had already been vaccinated, respondents with sufficient health literacy felt more positive about COVID-19 vaccination than those with insufficient health literacy ($t[180] = 4.168$, $p < 0.001$). In addition, teachers with sufficient health literacy felt more informed ($p < 0.001$) and less confused ($p < 0.001$) about COVID-19-related information than those with insufficient health literacy. Multiple linear regression analysis revealed that age ($\beta = 0.14$, $p = 0.011$) and the number of teaching hours per week ($\beta = -0.206$, $p < 0.001$) were significant predictors of the HLS-COVID score.

Conclusions: The findings of this study may serve as a guide for addressing health literacy gaps among school teachers.

KEYWORDS

COVID-19, teachers, school, Hong Kong, China, vaccine hesitancy, corona-related health literacy

Introduction

The coronavirus disease 2019 (COVID-19) pandemic developed rapidly, with the continuous emergence of variants, such as the Omicron and Alpha variants (1). Such a rapid pandemic development increased the need for individuals to acquire and apply accurate health information at a fast pace (2). However, the COVID-19 pandemic has been accompanied by changing guidelines, misinformation, inaccurate health information and rumors, resulting in an "infodemic," due to quick and widespread dissemination of both accurate and inaccurate information (3, 4). During the pandemic, social media platforms (i.e., Facebook, Twitter and TikTok) became significant sources of information sharing and searching. In fact, the use of social media platforms increased by 20–87% globally during the pandemic. A recent systematic review revealed that online social media platforms are vulnerable to the spread of incorrect information (5), as the vast amount of health information disseminated on these platforms lacks comprehensive verification (6). A study also revealed that a majority of adults had been exposed to COVID-19-related misinformation, either through social media or instant messaging platforms (7). Such an infodemic has highlighted a population's low level of health literacy as an underappreciated global public health issue (8). However, social media platforms are also central resources of reliable health information and real-time updates (2), as during the pandemic, the public were more dependent on digital resources due to social distancing policies that restricted personal activities and social gatherings. Thus, health literacy is crucial in this era, as this infectious disease crisis arrived at a time of information excess, and integrating all of the available information to make personal health behavioral choices may be challenging for many individuals (9). Moreover, scholars have used a context-specific approach to define the concept of critical health literacy in a pandemic (CHL-P). They define it as the skills required in a pandemic to recognize and effectively address the urgency of action at all levels, the complexity of causes and effects and the evolution of the scientific base. It has also been proposed that CHL-P encourages people to grow in their capacity to critically evaluate and reflect on the contextual requirements for effective behavior (10).

Health literacy and its consequences

Adequate health literacy is required to deal with the overwhelming amount of inaccurate health information. As defined by Sørensen et al. (11), health literacy refers to "knowledge, motivation, and competencies to access, understand, appraise, and apply health information in order to make judgments and take decisions in day-to-day life concerning healthcare, disease prevention, and health promotion to maintain or improve quality of life over the lifetime". The World Health Organization defines health literacy as the cognitive and social abilities that affect an individual's motivation and capacity to obtain, absorb and use knowledge to maintain and develop their health (12). Health literacy empowers a person to be proactive in maintaining their health and confers the ability to take action and make well-informed decisions. Limited health literacy has been found to be significantly associated with poor health status, high use of healthcare services, low socioeconomic status, lower education and older age (13). Studies have shown that limited health literacy is indirectly and directly associated with poor health and clinical outcomes (14–16). Data from different developed countries have demonstrated

that limited health literacy is associated with the declining use of public health services and information and disease prevention services and poorer self-management of diseases (17). Conversely, individuals with a higher level of health literacy have less frequent use of hospital services and better health status, due to greater disease knowledge, healthier behaviors, greater use of preventative treatment and greater drug compliance (18). Recent research has also demonstrated that health literacy may be seen as a social vaccine, as it enables individuals and communities to reduce the spread of viruses by comprehending and using the information supplied by governments and health authorities (19). Thus, adequate health literacy is essential to manage the current pandemic. Despite the concerns about and importance of COVID-19-specific health literacy, there is little empirical research on this topic, with only one study performed in Taiwan (20) and one in Germany (21). Thus, COVID-19-specific health literacy is a crucial research topic during this global health emergency.

Health literacy and COVID-19 vaccine hesitancy

In a recent study of COVID-19 vaccine hesitancy conducted in seven European countries, 18.9% of the sample of more than 7,600 respondents were uncertain of their intention to receive the COVID-19 vaccine, and 7.2% reported their unwillingness to be vaccinated (22). Studies have developed models, such as the 5C model (23), to integrate data regarding vaccination behavior. However, COVID-19 vaccines differ from previous vaccines in many aspects, such as the speed of their development, vaccine effectiveness and potential side effects (24). COVID-19 vaccine hesitancy has been shown to be dependent on context, place, time and the type of vaccine (25). A recent study of school principals in Taiwan reported that individuals with limited COVID-19-specific health literacy had a lower intention to be vaccinated against COVID-19 (20). Moreover, a study of Chinese college teachers and students found that the key factors influencing their reluctance to receive the COVID-19 vaccine were beliefs about the safety of the vaccines, attention to and awareness of vaccine-related news and chronic medical issues. However, students' vaccine hesitancy was unrelated to teachers' vaccine hesitancy (26). A recent French study conducted by Montagni et al. (27) also revealed that fake news detection scores of adults were associated with the intention to receive the COVID-19 vaccine. Altogether, these findings highlight that inadequate health literacy may affect individuals' hesitancy to receive the COVID-19 vaccine, as they may be concerned about its safety and affected by news about the vaccine. Misinformation may deeply influence their decision on whether to receive the vaccine. Thus, the association between inadequate health literacy and COVID-19 vaccine hesitancy is worth investigating.

Importance of health literacy in school personnel

Education is one of the social factors affecting the health literacy of the general population, especially children and adolescents, as they are at their most receptive period of life (28). The long-term development of children's and adolescents' health and well-being is expected to benefit from investments in health literacy (29, 30). Investing in health literacy system capabilities requires a systematic effort and transformation that may multiply and sustain over time and that is resilient to external trends and events, rather than relying solely on organizational and individual behavioral changes (31). Moreover, scholars have reported that improving health literacy across populations and systems is critical to achieving health equity (31). Consequently, it is important to recognize that health literacy in schools is a major public health issue (32). In this regard, schools have long been seen as a crucial setting in which to promote disease prevention and health promotion and develop the health literacy of students, teachers and administrators (33–36). The health literacy of children and adolescents has long been a popular research topic, but equal attention should be given to the health literacy of teachers, as they are responsible for enhancing the students' understanding of health-related topics. Peterson et al. (2001) defined teachers' health literacy as "the capacity of teachers to obtain, interpret and understand basic health information and services, with the competence to use such information and services in ways that enhance the learning of health concepts and skills by school students" (37). Teachers' health literacy may be as important as students' health literacy, as teachers are like health information providers, while students are the consumers (37). However, the prevalence of limited health literacy is concerning. A study of secondary school teachers in Sri Lanka and Iran found that the prevalence of problematic or inadequate health literacy was 31.5 and 50.6%, respectively (38, 39). In Turkey, a study of 500 teachers found that more than 70% of them had extremely low or low levels of health literacy (40). A survey of 1,000 educators conducted in Japan during the COVID-19 pandemic, using the European Health Literacy Survey Questionnaire (HLS-EU-Q47), revealed that educators had gained sufficient health literacy, with a score of 33.5 out of 50 (41). Under the context of COVID-19, a recent study of school principals in Germany revealed a prevalence of 29.3% for limited COVID-19-specific health literacy. These findings demonstrate that sufficient health literacy levels are place- and time-specific. Therefore, research on COVID-19-specific health literacy among school teachers in Hong Kong is urgently needed,

especially as research on this topic in Hong Kong has been limited for many years.

Health literacy in the context of work behavior and stress symptoms

Making appropriate health decisions based on relevant information may be beneficial in occupational and health settings (42). Studies have also shown that limited health literacy may be one of the barriers to the understanding and effectiveness of occupational training (43). A study of young adult workers also revealed that six components of their proposed health literacy structural model, namely, "self-perception," "a proactive approach to health," "self-control," "self-regulation" and "communication and cooperation," were associated with work ability (44). Although an Iranian study reported no significant relationship between job stress and health literacy (45), other studies have suggested that uncertainty related to COVID-19 has the potential to increase people's stress, anxiety, risk of burnout, fear and frustration levels (46–53). Educators have been accumulating negative psychological symptoms, such as stress, anxiety and depression, due to the closure of educational facilities globally and the need to adapt to new teaching methods since the beginning of the COVID-19 pandemic (54–56). A recent systematic review showed that the estimated prevalence of stress among teachers globally was 30% (57). In the context of Hong Kong, a local survey revealed that more than 85% of teachers felt stressed or over-stressed, and more than one third of people surveyed worked 61 hours or more per week (58, 59). These findings indicate that educators in Hong Kong are an occupational group experiencing a high level of stress since the beginning of the COVID-19 pandemic. In the context of a heavier workload and a greater need for self-management, researchers have hypothesized that self-endangering behavior, including work intensification, extensification and quality reduction, may be used as coping mechanisms (60). However, engaging in these behaviors may be harmful to one's physical health and long-term capacity for employment (60). Burnout syndrome, which includes psychosomatic complaints and exhaustion, and mild to severe mental disorders, such as anxiety and depression, may occur due to work overload or stress (61, 62). Therefore, investigating health literacy and its relationship to self-endangering work behavior and burnout syndrome may facilitate the development of interventions aimed at improving the mental health of teachers globally.

In Hong Kong, the health literacy level of the population is concerning. A recent study reported that 20.7% and 35.2% of the general population had inadequate or problematic health literacy levels, respectively (63). Inadequate levels of health literacy were also found to be prevalent among older adults in Hong Kong (64). However, the health literacy of teachers in Hong Kong has rarely been discussed, even though the unexpected digital revolution in teaching due to the COVID-19 pandemic has brought major teaching challenges, such as technical and motivational problems (65). According to a survey of 1,200 teachers in Hong Kong, conducted by the Hong Kong Federation of Education Workers in November 2020, 85% of teachers felt "relatively high" or "very high" levels of pressure at work during the pandemic. This prevalence is 5% higher than the prevalence reported in the previous year (66).

In this study, we aimed to examine COVID-19-related health literacy in teachers in Hong Kong and explore how different demographic variables are associated with health literacy and how health literacy levels predict the level of COVID-19-related information received, self-endangering work behavior and burnout symptoms. Moreover, we explored how COVID-19-related health literacy affected teachers' decisions regarding and attitudes toward vaccination.

Methods

This cross-sectional quantitative study was carried out with teachers in primary, secondary and special schools in Hong Kong from April 2021 to February 2022, which was during a period of strict social distancing measures. This study was designed within the framework of the COVID-HL Network, a global research network on health literacy related to COVID-19 that comprises more than 150 researchers from 70 countries (https://covid-hl.eu, accessed on 30 September 2022). The theoretical framework of the present study was health literacy and the infodemic and the survey was validated and adapted from Dadaczynski et al. (67). The survey was translated from English into traditional Chinese based on the conceptual, cultural and linguistic settings in Hong Kong. The translated version was reviewed and rephrased based on feedback from a pilot study of eight participants and the opinions of the authors.

Participant recruitment

The sample was composed of teachers in primary, secondary and special schools in Hong Kong. Participants were recruited through email invitations. English and Chinese versions of an online survey on the Qualtrics platform were sent to the principals of 1,130 schools, including 561 primary schools, 477 secondary schools and 36 special schools, registered with the Education Bureau in Hong Kong. The school principals were contacted *via* our established school network, with priori verbal agreement granted over the phone. Hardcopies of the surveys were mailed to 243 schools. In addition, we sent invitations *via* our personal and professional networks through social media platforms (e.g., WhatsApp), and respondents were asked

to invite eligible participants to participate. Participation was anonymous and voluntary and no incentives were provided. Confidentiality of information was guaranteed. The study protocol was approved by the research ethics committee of Hong Kong Baptist University (REC/20-21/0465).

Instruments

Demographic characteristics

Demographic characteristics, including sex, age (years) and school type (primary school, secondary school or special school), were ascertained.

COVID-19-related health literacy

The 22-item HLS-COVID-Q22 scale (21) was used to measure the participants' capacity to understand and utilize COVID-19-related health information. The validated scale has high internal consistency ($\alpha = 0.940$) and has been shown to be reliable for measuring COVID-19-related health literacy (21). The participants scored on a 4-point scale, from 1 (very difficult) to 4 (very easy), their perceived difficulties in accessing, understanding, appraising and applying health-related information in the context of the COVID-19 pandemic. Responses for the items were averaged to form the scale score, and the attainment of sufficient health literacy was indicated by an average score of 3. An average score less than or equal to 2.5 indicated inadequate health literacy, while an average score >2.5 but <3 indicated problematic health literacy (21). A Cronbach's alpha value of 0.957 was obtained in the present study.

Health information in the context of the COVID-19 pandemic: Attitudes toward vaccination

The adequacy and clarity of health information in the context of the COVID-19 pandemic were measured using the following two items: "On a scale of 1 (very informed) to 5 (insufficiently informed), how well-informed do you feel about the coronavirus or the COVID-19 pandemic?" and "On a scale of 1 (not at all confused) to 4 (very confused), do you feel confused about COVID-19-related information?" (21). The willingness to get vaccinated against COVID-19, if offered, was also measured on a 6-point scale, from "yes, certainly" to "certainly not", or "I am already vaccinated". Attitudes toward vaccination were assessed using five self-reported items. Examples of these items included "vaccinations are important to protect me and my family" and "vaccination is compatible with my attitudes". The participants were asked to rate their agreement of each item using a 4-point scale, from 1 (totally agree) to 4 (do not agree at all). The responses for the items were averaged to calculate the scale score.

Health promotion and disease prevention in schools

Health promotion and disease prevention in schools were measured using a 15-item questionnaire based on a study by Dadaczynski and Hering (67). The questionnaire measured a range of health issues addressed by schools in the context of the COVID-19 pandemic. The participants rated how they agree with the 15 statements (e.g., "students learned how to eat healthily despite the restrictions due to the coronavirus"), on a 4-point scale, from 1 (not true at all) to 4 (totally true). The responses for each item were summed and averaged to calculate the scale score. Higher scores indicated greater disease prevention and health promotion efforts at the school.

Exhaustion related to work and psychological discomfort

The three-item "exhaustion" subscale of the Burnout Assessment Tool was used to assess exhaustion related to work, while psychological discomfort was measured using the 5-item "psychosomatic complaints" subscale (68). The participants rated how often the statement applied to them on a five frequency-based response scale, from 1 (never) to 5 (always). The responses for each item were summed and averaged to calculate the total score. The Cronbach's alpha values of the exhaustion and exhaustion subscales in the present study were 0.932 and 0.801, respectively.

Self-endangering work behavior

Self-endangering work behaviors were assessed using three subscales of self-reported self-endangering work behavior scales (60), including "extensification of work" (six items), "intensification of work" (three items) and "work quality reduction" (three items). The reliability of the scale has been shown previously (60). The participants rated how often the statements applied to them in the past 3 months, on a 5-point scale from 1 (never) to 5 (very often).

Work-related information

The number of teaching hours per week, the number of working hours per week, the change in the number

of working hours per week due to the COVID-19 pandemic and the number of students at the school were collected. The participation status in health-promoting programmes at the participants' schools was also determined (never, <1 year, 1 to <2 years, 2 to <3 years, 3 years or above).

Perceived general health, presence of any chronic disease and impairment due to health problems

The general health of the respondents was assessed through the self-reported question "How is your overall health?", on a 5-point scale, from 1 (very good) to 5 (very poor). The participants were asked if they had any chronic or long-term health problems, answering 1 for "no" and 2 for "yes", and to rate the degree to which their chronic disease impaired their activities of daily living, on a 3-point scale from 1 (no impairment at all) to 3 (severe impairment) (69).

Statistical analysis

Continuous variables were reported using the mean (M) and standard deviation (SD). Categorical variables were computed as the number (n) and percentage. Mean differences in COVID-19-specific health literacy among demographic groups (i.e., by age, sex, type of schools and number of students) were explored using independent Student's *t*-tests. Potential predictors of COVID-19-specific health literacy levels (i.e., age, sex and level of health promotion and disease prevention in schools) were explored using adjusted multiple linear regression models. Separate adjusted multiple linear regression models were computed to detect the predictive power of COVID-19-specific health literacy for COVID-19 vaccine hesitancy. Adjusted multiple linear regression models were used to explore how COVID-19-specific health literacy affected one's perceived general health. Mean score differences in self-endangering work behavior (i.e., extensification of work, intensification of work and work quality reduction), burnout symptoms (i.e., exhaustion related to work situation and psychosomatic complaints) and the level of knowledge of COVID-19- or pandemic-related information were compared between health literacy groups using an independent samples Student's *t*-test or one-way analysis of variance (ANOVA). All data analyses were performed using SPSS 27.0 for Windows (IBM, Armonk, NY, USA). Statistical significance was defined as a p-value <0.05.

Results

Sample characteristics

Of the 366 teacher participants (Table 1), 46.4% were male, and the average age was 38.3 (SD = 9.72) years. Almost half of the participants (45.1%) worked in secondary schools, 33.8% in primary schools and 21.2% in special schools. The average number of teaching hours per week was 21.9 (SD = 10.15), and the average number of working hours per week was 45.4 (SD = 16.18, ranging from 4 to 115 h). The number of working hours per week was higher during than before the COVID-19 pandemic for 51.2% of the participants, about the same for 36.0% of the participants and lower during than before the COVID-19 pandemic for 12.7% of the participants. The average number of students at the school was 516.16 (SD = 315.9).

Differences COVID-19-related health literacy according to participants' characteristics

There was no significant sex difference in HLS-COVID scores (males: $M = 2.97$, SD = 0.41; females: $M = 2.98$, SD = 0.43). A one-way ANOVA revealed that there was a statistically significant difference in HLS-COVID scores between participants who worked in primary schools, secondary schools and special schools ($F_{[2,351]} = 12.59$, $p < 0.001$). Tukey's honestly significant difference (HSD) test for multiple comparisons showed that participants who worked in special schools had a significantly lower HLS-COVID score than those who worked in primary schools ($p < 0.001$, 95% confidence interval [CI] = −0.1699, −0.4036) or secondary schools (p < 0.001, 95% CI = −0.3467, −0.1235). There was no statistically significant difference in HLS-COVID scores between participants working in primary schools and those working in secondary schools ($p = 0.296$).

A one-way ANOVA revealed a statistically significant difference in HLS-COVID scores according to the change in the number of working hours per week during the pandemic ($F_{[2,349]} = 9.667$, $p < 0.001$). Tukey's HSD test for multiple comparisons found that participants with a higher number of working hours per week during the COVID-19 pandemic had significantly lower HLS-COVID scores than individuals with a lower number of working hours per week during the COVID-19 pandemic ($p = 0.03$, 95% CI = −0.2797, −0.0115) and individuals with no change in the number of working hours per week ($p < 0.001$, 95% CI = −0.3003,−1.1117). An independent samples Student's *t*-test revealed a statistically significant difference in HLS-COVID

TABLE 1 HLS-COVID by participants characteristics using *t*-tests and ANOVA ($N = 366$).

Variables		*N* (%)	HLS-COVID	
			Mean (SD)	*p*-value
Gender	Male	169 (46.6)	2.97 ± 0.41	0.727
	Female	195 (54.4)	2.98 ± 0.43	
Type of School	Primary schools	123 (33.8)	3.06 ± 0.46	<0.001**
	Secondary schools	164 (45.1)	3.01 ± 0.39	
	Special schools	77 (21.2)	2.77 ± 0.34	
Weekly working hours change	Lower than before the COVID-19 pandemic	46 (12.7)	3.03 ± 0.39	<0.001**
	About the same	130 (36.0)	3.09 ± 0.42	
	Higher than before the COVID-19 pandemic	185 (51.2)	2.88 ± 0.41	
Number of students at school	≤600	206 (57.9)	2.93 ± 0.39	0.009*
	600 or above	150 (42.1)	3.05 ± 0.46	
Level of informing on COVID-19 related information	Well or very well informed	105 (28.8)	3.15 ± 0.45	<0.001**
	Poor/satisfactory	260 (71.2)	2.91 ± 0.39	
Level of confusion due to COVID-19 related information	Not at all/a little confused	279 (77.3)	3.04 ± 0.39	<0.001**
	Quite confused/very confused	82 (22.7)	2.76 ± 0.45	
		Number	Mean (SD)	
Age		335	38.32 ± 9.72	
Number of students at school		349	516.16 ± 315.9	
Weekly working hours		358	45.4 ± 16.18	
Weekly teaching hours		356	21.9 ± 10.15	

SD, standard deviation.
*$p < 0.05$, **$p < 0.01$.

scores between the group of participants who had 600 or fewer students at their schools and the group of participants who had more than 600 students at their schools ($t_{[354]} = 2.274$, $p = 0.009$). The results also showed that the participants who felt well informed or very well informed about COVID-19-related information had significantly higher health literacy scores ($M = 3.15$, SD = 0.45) than those who felt insufficiently or poorly informed about COVID-19-related information ($M = 2.91$, SD = 0.39; $t_{[350]} = 5.38$, $p < 0.001$). The participants who felt not at all or a little confused about COVID-19-related information ($M = 3.04$, SD = 0.39) had higher health literacy scores than those who felt very confused.

Table 2 provides the descriptive statistics of health-related variables. The average total HLS-COVID-Q22 score for the total sample was 2.98 ± 0.42. Sufficient health literacy was observed in 50.8% of the participants, whilst 47.4% participants had insufficient health literacy (including problematic or inadequate literacy levels). The majority of the participants (71.3%) had insufficient, poor or satisfactory pandemic-related information, and 77.3% of the participants felt not at all or a little confused about pandemic-related information. Almost half of the participants (49.0%) had already received a COVID-19 vaccine. The total mean scores for attitudes toward vaccination, health promotion and disease prevention in schools and perceived general health were 2.13 (SD = 0.65), 44.6 (SD = 6.49) and 2.65 (SD = 0.80), respectively. Most of the participants (82.7%) did not present with any chronic disease or long-lasting health problems. The majority of the participants (72.4%) were not at all impaired by health problems.

Table 3 shows the descriptive statistics for work satisfaction, self-endangering work behavior (i.e., extensification of work, intensification of work and work quality reduction) and secondary burnout symptoms (i.e., exhaustion related to work situations and psychosomatic complaints) for the entire sample and the differences between the two health literacy groups: sufficient health literacy ($n = 186$) and insufficient health literacy ($n = 170$). Respondents with sufficient health literacy ($M = 2.95$, SD = 0.87) had significantly lower intensification of work scores than those with insufficient health literacy ($M = 3.23$, SD = 0.88; $t_{[352]} = 3.004$, $p = 0.003$). After excluding participants who had already been vaccinated, those who had sufficient health literacy ($M = 1.92$, SD = 1.09) scored lower for their attitudes toward COVID-19 vaccination (i.e., felt more positive about COVID-19 vaccination) than those with insufficient health literacy ($t_{[180]} = 4.168$, $p < 0.001$). In addition, teachers with sufficient health literacy ($M = 2.60$, SD = 0.72) felt more informed about COVID-19-related information than those with insufficient health literacy ($M = 2.97$, SD = 0.62; $t_{[354]} = 5.142$, $p < 0.001$). Moreover, those with sufficient health literacy (M

TABLE 2 Descriptive table of health-related variables in the sample ($N = 366$).

Variables		*n* (%)	
HLS-COVID-Q22	Sufficient health literacy	186 (50.8)	
	Problematic health literacy	130 (36.5)	
	Inadequate health literacy	40 (10.9)	
Level of informing on COVID-19 or pandemic related information	Well or very well informed	105 (28.8)	
	Insufficient/poor	260 (71.3)	
Level of confusion due to COVID-19 related information	Not at all/a little confused	279 (77.3)	
	Quite confused/very confused	82 (22.7)	
Coronavirus vaccination readiness	Certainly/Likely	119 (32.6)	
	Maybe	37 (10.1)	
	Certainly not/Unlikely	30 (8.2)	
	Already vaccinated	179 (49.0)	
Presence of any chronic disease or long-lasting health problem	No	301 (82.7)	
	Yes	63 (17.3)	
Impairment by health problems	Not at all impaired	260 (72.4)	
	Moderately impaired	93 (25.9)	
	Strongly impaired	6 (1.7)	
		Number	**Mean (SD)**
Covid-19-related health literacy (HLS-COVID-Q22)		356	2.98 ± 0.42
Attitudes about vaccination		358	2.13 ± 0.65
Health promotion and prevention in schools		355	44.6 ± 6.49
Perceived general health		364	2.65 ± 0.80

SD, standard deviation.

= 1.91, SD = 0.67) felt less confused about COVID-19-related information than those with insufficient health literacy (M = 2.24, SD = 0.63; $t_{[350]} = 4.68$, $p < 0.001$).

Multiple linear regression analyses were performed to explore the association between health literacy level and other potential influential factors (i.e., age, sex and number of working hours and teaching hours per week). Table 4 provides the regression coefficients for predicting the health literacy level. The model was adjusted for age and sex. A significant regression equation was found ($F_{[4,312]} = 6.500$, $p < 0.001$) with an R-squared value of 0.077. The results showed that age and the number of teaching hours per week were significant predictors of HLS-COVID scores. Specifically, age positively predicted the HLS-COVID score, and the number of teaching hours per week negatively predicted the HLS-COVID score. Separate multilinear regression models adjusted for age, sex and the presence of chronic illness were generated to predict attitudes toward vaccination (Table 5). The level of COVID-19-specific health literacy was negatively associated with attitudes toward COVID-19 vaccination, while the level of confusion about COVID-19-related information was positively associated with attitudes toward COVID-19 vaccination (i.e., less agreeable to vaccination; $F_{[6,158]} = 5.865$, $p < 0.001$), with an R-squared value of 0.182.

Discussion

The present study aimed to examine whether different demographic variables, workplace stress levels, levels of COVID-related information received and burnout-related behaviors were associated with health literacy in teachers in Hong Kong. This is one of the first studies to explore COVID-19-related health literacy and its associated factors in teachers in Hong Kong. We found that approximately half (50.8%) of the participants had sufficient health literacy, while 47.4% had "problematic health literacy" (36.5%) or "inadequate health literacy" (10.9%). The prevalence of inadequate health literacy (10.9%) in our study group was markedly lower than the prevalence previously reported in other groups (e.g., 50.9% in older adults) in Hong Kong and also lower than the reported in non-healthcare settings (46.9%) in Malaysia (70). In a recent study in Germany that focused on HLS-COVID scores, the prevalence of low health literacy (i.e., problematic or inadequate health literacy) in the general population ranged from 50.4% in the first wave of the COVID-19 pandemic (April 2020) to 38.2% in the third wave (December 2020) (71). The prevalence of limited health literacy was markedly lower in our study group than the prevalence reported in a sample of 1,360 participants in Shanghai, China (10.9% vs. 85%) (72). The mean

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TABLE 3 Work satisfaction, self-endangering work behavior and secondary burnout symptoms by health literacy level using *t*-tests ($N = 366$).

Health literacy level	Mean (SD)	Mean diff.	*p*	Mean (SD)	Mean diff.	p	Mean (SD)	Mean diff.	*p*
	Work satisfaction			**Exhaustion related to work situation**			**Psychosomatic complaints**		
Sufficient	3.05 (0.81)	−0.067	0.433	3.33 (0.94)	0.033	0.353	2.52 (0.78)	0.466	0.546
Insufficient	2.98 (0.77)			3.36 (0.88)			2.57 (0.66)		
	Extensification of work			**Intensification of work**			**Quality reduction**		
Sufficient	3.31 (0.80)	0.079	0.333	2.95 (0.87)	0.279	**0.003**	2.26 (1.02)	−0.027	**0.007**
Insufficient	3.39 (0.72)			3.23 (0.88)			2.53 (0.85)		
	Attitude about COVID-19 Vaccination			**Level of informing of COVID-19 related information**			**Level of confusion due to COVID-19 related information**		
Sufficient	1.92 (1.09)	0.705	**<0.001**	2.60 (0.72)	0.368	**<0.001**	1.91(0.67)	0.362	**<0.001**
Insufficient	2.62 (1.19)			2.97 (0.62)			2.24 (0.63)		

Bold figures indicates $p < 0.05$.
SD, standard deviation.

TABLE 4 Regression model of predicting health literacy by age, weekly working hours and teaching hours.

Variables	B(95%CI)	*β*	*p*
Gender	0.02 (−0.089, 0.093)	0.002	0.952
Age	0.001 (0.000,0.003)	0.140	**0.011**
Weekly working hours	0.003 (0.000, 0.006)	0.106	0.054
Weekly teaching hours	−0.009 (−0.013, −0.004)	−0.206	**<0.001**

Bold figures indicates $p < 0.05$.

TABLE 5 Regression model of predicting attitude about vaccination by age, sex, level of informing of COVID-19 related information and level of confusion due to COVID-19 related information.

Variables	B(95%CI)	*β*	*p*
Gender	0.68 (−0.263, 0.399)	0.030	0.684
Age	−0.02 (−0.005, 0.001)	−0.086	0.249
Covid-19-related health literacy	−0.817 (-1.251, −0.382)	−0.311	**<0.001**
Level of informing on COVID-19 related information	−0.046 (−0.013, −0.004)	−0.026	0.749
Level of confusion due to COVID-19 related information	0.332 (0.035, 0.628)	0.177	**0.029**
Presence of chronic illness or long-term health problem	−0.106 (−0.320, 0.109)	−0.071	0.333

Bold figures indicates $p < 0.05$.

HLS-COVID score observed in our study (2.98 ± 0.42) indicates that the participants attained sufficient health literacy; however, it was slightly lower than the average score reported for school principals in Taiwan ($M = 3.2$, SD = 0.4) (20). These findings demonstrate that the prevalence of low health literacy varies across different countries and regions, and the present study contributes part of the picture of COVID-19-specific health literacy among school personnel in Hong Kong. Even in this group of well-educated individuals, nearly half of them had a low level of health literacy. Therefore, interventions focusing on increasing health-related knowledge are urgently needed to improve health literacy among school teachers.

We found no significant difference in health literacy according to sex. This is in line with a study in Hong Kong which revealed no significant sex disparities in any aspect of health literacy (70). However, other studies have shown that females tend to have a higher level of health literacy than males (73, 74). A recent study in Taiwan also reported that female school principals tended to have a higher level of COVID-19-related health literacy (20). A study in Korea revealed that female adults tended to have a higher level of health literacy in the domains of learning about medical paperwork, directions on medication bottles and written information from their healthcare professional (75). Whilst these findings demonstrate that the effect of sex on health literacy remains varied, the

present study findings suggest that individuals with similar occupations do not have a sex difference in health literacy.

Significant differences were observed in health literacy between participants working in different types of school. Those working in special schools had a lower level of COVID-19-related health literacy than those working in either primary or secondary schools, but there was no statistically significant difference between participants who worked in primary schools and those who worked in secondary schools. There is no existing evidence for a lower level of health literacy among teachers working in special schools. However, a cross-sectional study of primary and secondary school teachers in Çorum, Turkey ($n = 580$) conducted in 2015 using the Newest Vital Sign scale revealed that there was no significant difference in the health literacy level between teachers working in primary and secondary schools (40). As there are few studies showing that working in different types of school affects health literacy, the significant difference detected in the current study may be attributable to the small sample of participants who worked in special schools. Further studies may be needed to validate this difference in health literacy according to school type.

Significant differences in health literacy were observed between participants who had a higher number of working hours per week during than before the pandemic and those with a lower or about the same number of working hours per week. However, a study of Filipino domestic workers revealed that the number of working hours per week was not associated with the health literacy level (76). Meanwhile, another study of 500 young Japanese nurses and care workers showed that working at their own pace, maintaining a work–life balance, regularly performing self-check-ups and attending lectures and workshops were factors that were significantly associated with a high health literacy level (77). This may explain our findings, as an increase in the number of working hours per week during the pandemic may have affected the working pace and work–life balance of the teachers. Thus, teachers may have had less time to access, understand and appraise vast amounts of health information during the COVID-19 pandemic.

In the present study, teachers with sufficient health literacy felt significantly more well-informed and significantly less confused about COVID-19-related information than those with insufficient health literacy. This finding was consistent with the finding of a study of HLS-COVID scores in the general population in Germany (21). As the perceived ease or difficulty in appraising health information is one of the core dimensions of health literacy, feeling less confused or better informed about health information may indicate a greater ability to appraise COVID-19-related information (11). A study also reported that a low level of health literacy is the underlying cause of confusion for many people when seeking health-related information (78). Consistently, the present study revealed that teachers with insufficient COVID-19-specific health literacy were more likely than those with sufficient literacy to be less informed and more confused about COVID-19-related information, which is similar to the situation for individuals with insufficient general health literacy. We found that age and the number of teaching hours per week were significant predictors of COVID-19-specific health literacy, with older age being associated with a higher level of literacy, and a higher number of working hours per week being associated with a lower level of literacy. Several studies in Europe, Taiwan and Australia have suggested that a young age is associated with limited health literacy in the general population (13, 79–82). In contrast, other studies have reported that old age is significantly associated with limited health literacy (40, 83). A health literacy study of community-dwelling individuals in Hong Kong reported that age was negatively correlated with the health literacy level (63). Further studies are needed to elucidate the association between age and health literacy, especially in the context of COVID-19.

We found that a higher number of working hours per week was associated with a lower level of COVID-19-specific health literacy. Although studies have shown that some of the dimensions of the constructed health literacy model, such as "self-regulation" and "self-perception," were associated with one's work ability (84), the relationship between workload, the number of working hours and health literacy has rarely been discussed. Assessing, understanding and appraising is a time-consuming process, and teachers may not have had time to select or distinguish accurate health information under the heavy workload they experienced during the pandemic (85). Additionally, our study revealed that teachers with insufficient health literacy had significantly higher frequencies of two types of self-endangering behaviors—"intensification of work" and "work quality reduction"—than those who had sufficient health literacy. As mentioned, a previous study demonstrated that health literacy may be associated with work abilities (84). However, research exploring the relationship between health literacy and self-endangering work behavior is lacking. Studies have proposed that self-endangering work behavior is a form of coping in response to work overload (60). Further studies may be needed to explore whether teachers with limited health literacy are more likely to experience work overload and perform self-endangering work behavior.

Teachers who had sufficient health literacy had a significantly lower score for their attitudes toward vaccination (i.e., had a more positive attitude) than teachers with insufficient health literacy. Similarly, our regression model demonstrated that a more positive attitude toward vaccination was associated with a higher level of COVID-19-related health literacy. This finding is consistent with the finding of a COVID-19-related health literacy study of Taiwanese school principals, in which principals with higher COVID-19-related health literacy reported a lower level of vaccine hesitancy (20). However, a previous systematic review also concluded that the relationship between health literacy and vaccine intention remains unclear, as COVID-19 vaccine hesitancy or acceptance was found to be

affected by factors including the country, age and type of vaccine (86). Thus, improving teachers' COVID-19-related health literacy may also be a strategic approach to improve teachers' individual vaccine acceptance. However, vaccine acceptance may also be influenced by other factors, such as age and the type of vaccine. Thus, further studies are needed to facilitate our understanding of the relationship between health literacy and vaccine acceptance.

Study limitations

This study has some limitations. First, we used a purposeful convenience sample, which precludes the generalisability of the findings, as they may not be typical of all school teachers. Second, the cross-sectional nature of the study is a shortcoming, as it only allowed the examination of associations between variables, and not causality. This design also hindered our understanding of changes in the variables over time. Third, the participants' responses were collected on a self-reported basis. The validity of our study findings may be limited due to "social desirability" bias, that is, teachers may have tended to respond with well-accepted social behaviors in the questionnaire. However, it is worthwhile to note that the teacher participants were informed about the anonymity of their responses. Fourth, to increase the response rate, the sampling duration was extended to 11 months, which covered the third and fourth waves of the COVID-19 pandemic in Hong Kong. During this time, Hong Kong transitioned between half-day face-to-face lessons at schools and virtual learning at home. The change to online learning and teaching may have led to an underestimation of the changes in workload during the COVID-19 pandemic. Furthermore, most of the data were gathered when the Hong Kong immunization programme was in its early stages and vaccination pass procedures had not yet been implemented. As a result, the attitudes and readiness toward vaccination may not be applicable to the current situation in Hong Kong. Future studies should validate the findings by using a larger, more representative sample.

Conclusions

The present study contributes to our understanding of health literacy among school teachers in Hong Kong. Our study findings revealed the prevalence of limited health literacy among school teachers in Hong Kong, as almost half of the teachers had "problematic health literacy" or "inadequate health literacy". Data from the present study also indicate that a higher level of COVID-19-related health literacy among teachers is associated greater knowledge of pandemic-related information, less confusion about COVID-19-related information, a more positive attitude toward vaccination, a higher level of health promotion and disease prevention in schools, a lower level of psychosomatic complaints and better perceived general health.

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 human participants were reviewed and approved by Research Ethics Committee of Hong Kong Baptist University (REC/20-21/0465). The participants provided their written informed consent to participate in this study.

Author contributions

Conceptualization and study design: SL, PA, AL, KD, and OO. Coordination of the study: SL, JM, and EC. Funding requisition: SL. Data collection: SL, JM, EC, PA, and AL. Data analysis and writing up of the manuscript: SL and ES. Review of the manuscript: SL, ES, JM, EC, PA, KD, and OO. All authors have read and agreed to the published version of the 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.

Publisher's note

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EDITED BY
Yihui Du,
University Medical Center Groningen, Netherlands

REVIEWED BY
Mingquan Lin,
Cornell University, United States
Boran Zhou,
MedStar Georgetown University Hospital, United States

*CORRESPONDENCE
Wenwu Ling
lingwenwubing@163.com

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International curriculum for undergraduate sonographer education in China during the COVID-19 era: International remote teaching mode vs. domestic on-site teaching mode

Tingting Qiu, Qiang Lu, Yan Luo and Wenwu Ling*

Department of Medical Ultrasound, Sichuan University West China Hospital, Chengdu, China

Background: Sichuan University West China Medical School was the first institution in China to develop an undergraduate sonographer education program in 2016. This program was certificated by American Registry for Diagnostic Medical Sonography (ARDMS) and students are qualified for the ARDMS credential verification test. In this 4-year program, the international curriculum of ultrasound physics and hemodynamics was set for students in the third year since 2018. This study is aimed to compare the teaching effect of international remote teaching mode and domestic on-site teaching mode of this international curriculum before and during the COVID-19 pandemic.

Methods: All undergraduate sonographer students after completing ultrasound physics and hemodynamics in the academic years 2018–2019 (30 students; before the COVID-19 pandemic) and 2020–2021 (47 students; during the COVID-19 pandemic) were included in the study. The scores of 77 students were analyzed for their curriculum. Independent samples *t*-test or Mann–Whitney test was employed to compare students' scores before and during the COVID-19 pandemic. The Chi-square test was used to compare students' feedback about this curriculum through an online self-administered questionnaire. A $p < 0.05$ was considered statistically significant.

Results: Total scores were comprised of four parts: in-class tests, homework, mid-term, and final exam scores. The mean in-class test score for domestic on-site teaching mode during the COVID-19 pandemic was significantly higher than that for international remote teaching mode before the COVID-19 pandemic. However, there was no observed a statistically significant difference in homework, mid-term, final exam, and total scores between the two types of teaching modes. For questionnaire feedback, no significant difference was observed between the two groups regarding the satisfaction toward teachers, class atmosphere, teaching mode, curriculum content, exam difficulty, scores, and knowledge students gained. For the overall evaluation of the curriculum, 73.3% (22/30) of students were very satisfied before the COVID-19 pandemic, while 44.7% (21/47) of students felt very satisfied during the COVID-19 pandemic ($p = 0.02$).

Conclusion: The general teaching effect of domestic on-site teaching mode during the COVID-19 pandemic was comparable to that of international remote teaching mode before the COVID-19 pandemic, and domestic on-site teaching mode may provide a better in-class teaching effect.

KEYWORDS

undergraduate medical students, sonographer education, teaching mode, COVID-19, remote teaching and online learning, on-site teaching

Introduction

Coronavirus disease 2019 (COVID-19) was declared a pandemic by the World Health Organization (WHO) since its existence on 11 March 2020, with reported so far over 600 million cases around the world and over 6.5 million deaths (1). During the COVID-19 era, the educational environment has experienced long-lasting changes. Teaching *via* the internet has mostly replaced classroom traditional face-to-face lectures (2–4). Although online distance learning is reported to be acceptable and may increase the retention of information, the absence of a classroom learning atmosphere and a decrease in on-site interaction with teachers or classmates is questionable (5, 6). With the adaptation of mass vaccinations and strict anti-virus actions in China, the COVID-19 pandemic reached a plateau, which provided chances for face-to-face classroom teaching.

Sichuan University West China Medical School was the first medical educational institution in China to develop an undergraduate sonographer education program in 2016. This is a certificate program provided by American Registry for Diagnostic Medical Sonography (ARDMS) for which the students have to qualify for the ARDMS credential verification test. Based on the cooperation with Thomas Jefferson University, this program follows a student-centered, problem-based, and clinical practice-oriented curriculum. International curriculum ultrasound physics and hemodynamics is a foundation and an integral part of the academic courses, which is also a prerequisite for the Sonography Principle and Instrumentation test of ARDMS (7, 8). It is scheduled for the third-year students of this 4-year program. This program enhances the knowledge of the students of ultrasound techniques and their applications in clinical medicine and propels the certification of the role of a sonographer in the Chinese medical system.

As a new education program in China, the basic curriculum of ultrasound physics and hemodynamics was first delivered online *via* cisco Webex by an experienced sonographer educator from Thomas Jefferson University in the autumn semester of 2018 and 2019. However, after the COVID-19 outbreak, this online international remote teaching mode was unsustainable. Therefore, domestic on-site teaching mode was used in 2020 and 2021.

Materials and methods

Study design

This retrospective study compared the teaching effect of two types of teaching modes (international remote teaching mode *vs.* domestic on-site teaching mode) for undergraduate sonographer students before and during the COVID-19 pandemic. In-class tests, homework, and mid-term and final exam papers were submitted by these students upon completing the international curriculum ultrasound physics and hemodynamics in the academic years 2018–2019 (before the COVID-19 pandemic) and 2020–2021 (during the COVID-19 pandemic). The scores of these papers were analyzed in order to study the difference, if any, in students' performance toward the different teaching modes for this international curriculum. An online self-administered questionnaire was used to collect feedback from students after they completed this curriculum.

Curriculum setting

This international curriculum was composed of 8 chapters including physical principles, interactions of sound with tissue, ultrasound transducers, transducer care and maintenance, imaging principles and instrumentation, the transmission of ultrasound, reception of ultrasound, imaging artifact, Doppler imaging concepts, quality assurance and lab accreditation, and new technologies. Each chapter was introduced in a 90-min class each week. The in-class test was a collaborative assignment consisting of 10 single-choice questions carried out for 10–15 min in class. Homework was an independent assignment containing 15 questions (question types: filling in the blanks, true or false, single choice) after class. The mid-term exam was a review of the first 4 chapters' contents and this test was made up of 50 single-choice questions. The final exam paper was designed using single-choice, multiple-choice, short-answer, and subjective questions, which was a summary of this curriculum. All tests were in English. Total scores for each student were composed of in-class test average score (30%), homework average score (30%), mid-term (10%), and final exam score (30%).

FIGURE 1
International remote teaching mode, this mode was performed through a live video lecture by an American associate professor completely in English.

Teaching mode

In the academic years 2018–2019 (before the COVID-19 pandemic), international remote teaching mode was used for each class. This mode was performed through a live broadcast lecture by an American associate professor in full English (Figure 1). In the academic years 2020–2021 (during the COVID-19 pandemic), a domestic on-site teaching mode was applied for each class. This on-site teaching mode was carried out by four Chinese teachers (two professors, one associate professor, and one lecturer) in English. Each Chinese teacher was responsible for handling two chapters (Figure 2). All the students and Chinese teachers passed the College English Test Band-6 exam. All the Chinese teachers were found to have fluent oral English.

Online questionnaire

An online self-administered questionnaire (Supplementary material) was developed to evaluate the students' feedback upon completing the international curriculum for ultrasound physics and hemodynamics. The completion of this questionnaire was not mandatory but strongly encouraged. The questionnaire consisted of two main sections: the first part was intended to collect general information, whereas the second part was designed to collect students' feedback about the curriculum before the COVID-19 pandemic and during the pandemic by using eight items. For detailed information about those items and response options of the questionnaire items, please refer to the Supplementary material.

Sample size

All undergraduate sonographer students who have completed the international curriculum ultrasound physics and hemodynamics in the academic years 2018–2019 (30 students; before the COVID-19 pandemic) and 2020–2021 (47 students; during the COVID-19 pandemic) were included in the study. The scores and responses of 77 students were analyzed for this curriculum.

FIGURE 2
Domestic on-site teaching mode, this mode was carried out by a Chinese teacher in English.

Data collection

Data were collected based on in-class tests, homework, mid-term, and final exam papers along with online self-administered questionnaires received for the academic years 2018–2019 and 2020–2021.

Statistical analysis

Statistical analysis was conducted using GraphPad Prism, version 8.0. Continuous variables were presented as mean and standard deviation (SD) or median and interquartile range. Categorical variables were presented as frequencies and percentages. Unpaired *t*-test or Mann–Whitney test was used to compare students' performance on international curriculum ultrasound physics and hemodynamics before and during the COVID-19 pandemic. The Chi-square test or Fisher's exact test was used to compare students' responses to the questionnaire items. A $p < 0.05$ was considered statistically significant.

Ethical considerations

This study was approved by the Research and Ethics Committee of West China Hospital of Sichuan University. The names of students were kept anonymous. All data were kept confidential.

Results

Comparison of students' scores for ultrasound physics and hemodynamics before and during the COVID-19 pandemic

A total of 77 undergraduate sonographer students (age range 19–22 years old, female $n = 55$, male $n = 22$) participated in the present study. A total of 30 students participated before the COVID-19 pandemic (international remote teaching mode), and 47 students participated during the COVID-19 pandemic

TABLE 1 Test scores of curriculum ultrasound physics and hemodynamics between two teaching modes.

Teaching mode/test scores (100 points)		International remote teaching mode	On-site teaching mode	*p* value
		Before COVID-19 pandemic; $n = 30$	During COVID-19 pandemic; $n = 47$	
In-class test	Minimum	81	67	0.0025
	Maximum	98	100	
	Average	93	97	
	Standard deviation	4.1	5.6	
Homework	Minimum	83	86	0.3359
	Maximum	100	99	
	Average	95	95	
	Standard deviation	4.7	3	
Mid-term exam	Minimum	60	78	0.0943
	Maximum	100	100	
	Average	92	90	
	Standard deviation	11.1	7.4	
Final exam	Minimum	22	27	0.6268
	Maximum	98	100	
	Average	74	76	
	Standard deviation	19.6	15.6	
Total score	Minimum	70	70	0.2929
	Maximum	99	98	
	Average	88	90	
	Standard deviation	7.6	5.7	

(on-site teaching mode). The average score of the in-class test, homework, mid-term and final exam between the two groups was 93 vs. 97 ($p = 0.0025$), 97 vs. 96 ($p = 0.3359$), 92 vs. 90 ($p = 0.0943$), 74 vs. 76 ($p = 0.6268$). The total score between the two groups was 88 vs. 90 ($p = 0.2929$) (Table 1).

Comparison of students' responses toward ultrasound physics and hemodynamics before and during the COVID-19 pandemic

A total of 77 feedbacks for the curriculum were received, of which 30 responses were assessments of the international remote teaching mode before the COVID-19 pandemic. The rest 47 responses reflected students' subjective evaluations of the on-site teaching mode during the COVID-19 pandemic. As illustrated in Table 2, no significant difference was observed between the two groups for the satisfaction toward teachers, class atmosphere, teaching mode, curriculum content, exam difficulty, scores, and knowledge students gained. However, for the overall evaluation of the curriculum, 73.3% (22/30) students were very satisfied before the COVID-19 pandemic, while 44.7% (21/47) students felt very satisfied during the COVID-19 pandemic ($p = 0.02$).

Discussion

The undergraduate sonographer education program was initiated in China in 2016. Based on the cooperation between West China medical school and Thomas Jefferson University, this program enhanced the sonographer training system and alleviated the shortage of medical ultrasound professionals in China (9–12). In 2018 and 2019, ultrasound physics and hemodynamics, one of the academic courses for this program, was delivered in international remote teaching mode. With the COVID-19 pandemic outbreak, the educational environment has changed (13–15)and domestic on-site face-to-face teaching mode was adopted for this curriculum in the post-COVID-19 era.

This retrospective study compared international remote teaching mode and domestic on-site teaching mode for the theoretical medical curriculum ultrasound physics and hemodynamics. The results of students' scores showed that no significant difference was observed for homework, mid-term, final exam score, and total score between the two types of

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TABLE 2 Satisfaction questionnaire of curriculum ultrasound physics and hemodynamics between two teaching modes.

Teaching mode/questionnaire		International remote teaching mode		On-site teaching mode		*p* value
		Before COVID-19 pandemic; *n* = 30		During COVID-19 pandemic; *n* = 47		
		n	%	*n*	%	
Curriculum teacher	Very satisfied	23	76.7	29	61.7	0.3133
	Satisfied	7	23.3	16	34	
	Neutral	0	0	1	2.1	
	Not satisfied	0	0	1	2.1	
Class atmosphere	Interesting	24	80	39	83	0.7565
	Neutral	6	20	7	14.9	
	Boring	0	0	1	2.1	
Teaching mode	Very satisfied	19	63.3	24	51.1	0.2076
	Satisfied	7	23.3	18	38.3	
	Neutral	4	13.3	4	8.5	
	Not satisfied	0	0	1	2.1	
Curriculum content difficulty	Difficult	3	10	8	17	0.513
	Neutral	27	90	39	83	
	Easy	0	0	0	0	
Exam difficulty	Difficult	0	0	4	8.5	0.25
	Neutral	29	96.7	41	87.2	
	Easy	1	3.3	2	4.3	
Curriculum scores	Very satisfied	7	23.3	13	27.7	0.8407
	Satisfied	17	56.7	23	48.9	
	Neutral	6	20	10	21.3	
	Not satisfied	0	0	1	2.1	
Curriculum knowledge	Very satisfied	17	56.7	21	44.7	0.3492
	Satisfied	12	40	24	51.1	
	Neutral	1	3.3	2	4.3	
	Not satisfied	0	0	0	0	
General assessment	Very satisfied	22	73.3	21	44.7	0.02
	Satisfied	8	26.7	25	53.2	
	Neutral	0	0	1	2.1	
	Not satisfied	0	0	0	0	

teaching modes, which indicated that the general teaching effect of the two types of teaching modes was comparable. These results are in line with studies finding that digital transformation of the theoretical medical curriculum can be feasible during the COVID-19 pandemic (16, 17). However, it's noted that students' in-class test score under domestic on-site teaching mode was significantly higher than that under international remote teaching mode. This phenomenon may be due to the more active class learning atmosphere or interactions of on-site face-to-face teaching mode compared to distance learning online (17, 18). Several studies also emphasized the importance of classroom teaching interactions in the teaching process (19–22). Another interesting result was that the average score of the final exam was significantly lower than that of other forms of testing in both international remote teaching mode and domestic on-site teaching mode. Because, first, in-class tests and homework included testing contents of only one chapter, mid-term exams contained testing contents of the first four chapters. The final exam tested the whole eight chapters' key points, which was relatively more difficult. Second, as described in the methods curriculum setting part, the in-class test, homework, and mid-term exam mainly (>90%) contained single-choice question type, while the final exam paper was designed using single-choice, multiple-choice, short-answer, and subjective questions, which also increased difficulty.

Online questionnaire responses revealed that students' stratifications toward teachers, class atmosphere, teaching mode, curriculum content, exam difficulty, scores, and knowledge were

similar between the two groups. This indicated that two types of teaching modes were acceptable for this theoretical medical curriculum. However, students before the COVID-19 pandemic expressed significantly higher levels of general satisfaction with the curriculum as compared to that during the COVID-19 pandemic. One possible explanation for this finding is the freshness of this brand-new curriculum and teaching mode in China before the COVID-19 pandemic. Before the COVID-19 outbreak, classroom face-to-face lectures are a daily teaching mode for undergraduate students. Therefore, the international remote teaching mode at that time was unique and interesting for most students. This may lead to higher levels of general satisfaction with the curriculum. Similar feedback was reported by studies on transforming didactic face-to-face lectures into online sessions, workshops, or seminars that appear to be more attractive to medical students (23).

Despite the relatively higher general satisfaction rate among undergraduate sonographer students toward the curriculum under international remote teaching mode in this study, higher in-class test scores under domestic on-site teaching mode highlighted the importance of face-to-face experiences and classroom interactions. As a theoretical medical curriculum, the transformation from international remote teaching mode to domestic on-site teaching mode was successful, which also improved the in-class teaching effect. In the background of the COVID-19 pandemic and within the context of learning medical knowledge, a hybrid of the two types of teaching mode along with hands-on training would be more suitable and considerable in the future. In line with the recommendations from other studies (17, 24), we encourage educators to use hybrid strategies to improve the experiences of medical students in learning medical concepts and skills.

In conclusion, the general teaching effect of domestic on-site teaching mode during the COVID-19 pandemic was comparable to that of international remote teaching mode before the COVID-19 pandemic, and domestic on-site teaching mode may provide better in-class teaching effects.

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 human participants were reviewed and approved by Research and Ethics Committee of West China Hospital of Sichuan University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

Conceptualization, funding acquisition, and writing—original draft: TQ. Methodology and writing—review and editing: TQ, QL, YL, and WL. Investigation and project administration: TQ and WL. Visualization: QL, YL, and WL. Supervision: YL and WL. All authors have reviewed and approved the manuscript, contributed to the article, and approved the submitted version.

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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.2022.1083108/full#supplementary-material

SUPPLEMENTARY DATA SHEET 1
Satisfaction questionnaire of international curriculum ultrasound physics and hemodynamics.

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EDITED BY
Hubing Shi,
Sichuan University, China

REVIEWED BY
Changle Li,
Inner Mongolia Medical University, China
Xiaomin Song,
BeiGene, China

*CORRESPONDENCE
In-Hwan Oh
✉ parenchyme@gmail.com

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Health-related factors leading to disabilities in Korea: Survival analysis

TaeEung Kim[1], So-Youn Park[2] and In-Hwan Oh[1]*

[1]Department of Preventive Medicine, School of Medicine, Kyung Hee University, Seoul, South Korea, [2]Department of Medical Education and Humanities, School of Medicine, Kyung Hee University, Seoul, South Korea

The purpose of this study is to analyze (a) population and socioeconomic factors affecting disability, excluding the occurrence of disability due to accidents and congenital diseases, and (b) health-related behavioral factors and factors that can prevent and reduce the cause of disability due to disease in Korea. This study was a longitudinal research. Data were obtained from The 2018 Korean Health Panel (KHP) is a survey jointly conducted by the Korea Institute of Health and Social Affairs and the National Health Insurance Service. A total of 7, 372 (*Mage* = 52.14, SD = 21.39; Male = 47.52%) were analyzed in this study. People with Higher education attainments and more income levels were associated with lower hazard of developing new disabilities (all $p < 0.05$). In this study, the health factors that could be related to the occurrence of new disabilities were smoking, alcohol consumption, physical activity, and stress (all $p < 0.0001$). However, physical activity was negatively associated with the risk of developing a disability at all follow-ups ($p < 0.05$). Higher scores on the number of chronic diseases (valid scores = 0, 1, 2, 3, or more) represented a greater level of newly developing disability present at all follow-ups (all $p < 0.0001$). This longitudinal study confirmed the relationship between health-related factors and specific chronic diseases. Its findings can be used as a crucial foundation for establishing healthcare policies and services that can lower and prevent disability by preventing and reducing specific negative health behaviors and unhealthy behavioral factors, and alleviating chronic diseases in Korea.

KEYWORDS

health-related factors of disabilities, comorbidity, chronic diseases, longitudinal study, Korea

1. Introduction

As per a recent report by the World Health Organization (WHO), more than 1 billion people live with some form of disability, of which nearly 200 million face significant physical and mental difficulties (1). Almost everyone is likely to experience some form of disability (temporary or permanent) at some point in their lives; however, it has been found that the COVID-19 pandemic has disproportionately affected people with disabilities (1). The number of people with disabilities is increasing rapidly owing to demographic trends and an increase in chronic health conditions

(e.g., diabetes, cardiovascular disease, cancer, and mental health disorders), among other causes (2). The global direct cost of all disabilities among individuals was between 11 and 69% of the total income, and the cost accounted for by the governments of the Organization for Economic Cooperation and Development (OECD) countries was ∼10% of public social spending (2).

According to the Korea Disabled Persons Survey, as of May 2020, ∼260 million people with disabilities (5.1% of the total population) are registered. As of 2020, the number of people with disabilities had increased by about 420,000, showing a steady increase compared to 2017 (3). According to an analysis of the socioeconomic costs of major diseases for health insurance policy establishment in 2017 (4), the socioeconomic cost of disability is significant to a societal set-up, and in Korea, it was observed that it substantially burdened the country's economy (4). In terms of the socioeconomic costs of mental and behavioral disorders in Korea, direct costs amounted to KRW 7.557 trillion (∼$6.685 billion) and indirect costs to KRW 3.7705 trillion (about $3.335 billion) (4). Medical expenses and productivity loss accounted for a large portion of socioeconomic costs due to disability.

Disability types are influenced by trends in the individual's various health conditions and in environmental and other factors, such as road traffic accidents, natural disasters, conflict, diet, and substance abuse (5). Results from the World Health Survey show that the prevalence of disability in lower-income countries is higher than that in high-income countries. People in the poorest quintiles of wealth, women, and older adults also had a higher prevalence of disability (1). People who are unemployed and those with low incomes or those poorly educated are at a higher risk of disability (1, 2).

Occupational accidents, traffic accidents, and diseases have been commonly reported as the causes of disability. Diseases, such as cancer, heart attack, tuberculosis, pneumonia, diabetes, and cerebrovascular disease, are the most common causes of these disorders (5). Musculoskeletal disorders are the leading cause of disability, including arthritis, back pain, spinal/joint disease, and fibromyalgia (5). Furthermore, obesogenic lifestyle choices and personal behaviors (e.g., lack of exercise, high-calorie intake, sedentary lifestyle, smoking, alcohol consumption, stress, and psychological instability) are leading contributors to newly developing disabilities (5).

Previous studies that examined factors related to the development of various disabilities, except for war, terrorism, and traffic accidents, include original studies (6–52) and meta-analyses and review research (53–57). Most studies have investigated the socioeconomic characteristics [e.g., income level, (8, 9, 14, 17, 20) and education level (8, 14, 17, 18, 20)] of the population and the development of disability with respect to specific age and status [e.g., children, (10, 20) young and middle-aged adults, (14, 16, 19, 26, 42, 48, 50) veterans (35), and seniors and the older adults (6–8, 11, 17, 18, 22, 25, 28, 31, 32, 34, 39)]. Furthermore, many studies have identified that certain chronic diseases like hypertension, hyperlipidemia, joint, kidney and diseases [e.g., hypertension, (8, 19, 22, 30, 41, 43) hyperlipidemia (19), diabetes, (8, 30, 35, 36, 40, 41, 51, 55, 57) cerebrovascular disease (18, 30, 51), respiratory and lung disease (15, 30, 43, 45, 50, 57), cardiovascular disease (11–13, 30, 32, 45, 57), heart disease (35, 41, 46, 51), hip joint disease (30, 58), tuberculosis (54), kidney disease (44), HIV (14), cancer (30, 41, 57), and BMI/obesity (9, 19, 21, 22, 26, 27, 29, 32, 36, 39, 41, 45), etc.] or health-related factors, behaviors and choices [e.g., level of physical activity (6–9, 16, 27, 28, 31–34, 38, 42, 44, 56), smoking (9, 19, 32, 48, 49, 56), alcohol consumption (9, 32, 56), stress, anxiety, depression and dementia (8, 18, 30–32, 40, 45–47, 52)], are associated with a specific disabilities [e.g., physical disability (11, 16, 22, 25–31, 34, 35, 38–41, 49, 55, 59, 60), visual impairment (8, 10), hearing impairment (8), intellectual disability (41), developmental disability (41), mental disorder (8, 12, 13, 41, 56), respiratory disorder (15)].

Many studies have been conducted on various chronic diseases (disorders) and health-related behaviors; however, only a handful have analyzed the factors leading to the development of new disabilities. Thus, only a little is known about the risk of disability associated with health-related factors and chronic diseases in the development of new disabilities. Although several reviews (53–57, 61) and studies on the factors of the development of disability (6–52, 62) have summarized the evidence of a relationship between specific chronic disorders, health-related behaviors, and disability, no analysis thus far has estimated this risk in a longitudinal setting. Accurate estimation of the risk of disability associated with these factors is pivotal to understanding the health requirements that help with the prevention of disability onset among the concerned population.

This study analyzes (1) population and socioeconomic factors affecting disability, excluding the occurrence of disability due to accidents and congenital diseases, and (2) health-related behavioral factors and factors that can prevent and reduce the cause of disability due to disease. The specific research questions were as follows.

a. Health-related factors that can precipitate obesity, including smoking, alcohol consumption, lack of physical activity, and stress, are related to newly developed disabilities.

b. Chronic diseases (e.g., hypertension, diabetes, hyperlipidemia, arthropathy, tuberculosis, ischemic heart disease, and cerebrovascular disease) are associated with the new occurrence of disability.

2. Methods

2.1. Data source

The Korean Health Panel (KHP) (63) is a survey jointly conducted by the Korea Institute of Health and Social Affairs and the National Health Insurance Service and is utilized as basic

data for establishing healthcare policies and health insurance policies by identifying changes in healthcare costs and medical expenditures. The first survey began in 2008, and as of January 2021, currents data was released to the 13th in 2018. The number of households to which the first survey (first half of the 2008 survey) was administered was 7,866 and the number of household members is 24,616. In the 13th survey in 2018, the number of households was 5,838, including 4,232 (equivalent to the first sample) and 1,606 (equivalent to the second sample) households. The total number of household member was 17,008. The rate of maintenance of the original households in 2018 was 53.8% in the first sample and 72.3% in the second sample.

The KHP survey method is based on the computer-assisted personal interviewing (CAPI) method, in which researchers visit households to be surveyed and respond to the questions using laptops (63). For the composition and training of the survey team, a surveyor in charge of panel households in each region was assigned, and training was conducted on the survey contents and guidelines. A health household account book for 1 year of medical use was prepared by panel households, and receipts and year-end settlement data were collected. A CAPI-based survey was conducted by visiting panel households, and health account books and medical receipts collected from panel households were checked. As a result of the household and household member survey responses, overall cleaning was performed on the medical use history and receipt data collected by households. Annual data has been constructed based on the survey responses and medical usage details entered by panel households and surveyors.

The Korean medical panel is divided into two broad groups: the contents of the survey for households and those of the personal survey for individual household members. For households, we investigated the household's socioeconomic characteristics, income and expenditure status, contents of medical service use, cost of purchasing general medicines, status of private medical insurance, and surveyed individual household members on chronic disease management, health level, health lifestyle, and medical accessibility.

The relevant institutional review board approved this study. All study participants agreed to participate in information provision (written or spoken) and to disclose information provision (written or spoken) data.

2.2. Study participants

The disability information presented in the Korea Health Panel Survey data (63) is divided into four categories, as shown in Table 1. During the study period, each year the participants were asked whether they had a disability, which reflected their existing disability status. The first category comprises the attributes of a disabled individual, who has been diagnosed with a disability and is registered with the Ministry of Health and Welfare as a disabled person (64). The second category is of no disability, and the third category highlights the attributes of a disabled person who has been diagnosed with a disability but has not been registered as a disabled person with the Ministry of Health and Welfare. The last category incorporates the status of a disabled individual who is not registered as disabled, and not judged by the Ministry of Health and Welfare as one or those awaiting a decision regarding the disability (64). In 2008 and 2009, participants were not asked whether they had a disability, and Table 1 shows the detailed status of disability registration in the Korea Health Panel (2008–2018).

This study included the following 15 types of disabilities designated by the Korean Ministry of Health and Welfare (64) including physical disabilities, brain lesion disorders, visual impairments, hearing impairments, speech disorders, intellectual disability, developmental disorders, mental disorders, kidney disorders, heart disorders, respiratory disorders, liver disorders, facial disorders, elongated and urinary tract disorders, and epilepsy disorders. For this study, along with disabled individuals, identified by the Korean government, we also included persons with disabilities who were not officially diagnosed and confirmed by the government. This is because it takes ∼2 years in Korea to collect data regarding the final examination and registration of disabilities using a self-reporting method (64).

This study analyzed the time effects of health-related factors on the occurrence of new disabilities. As shown in Table 1, information on disabilities has been collected since 2010. Therefore, this study aimed to determine whether there is a new disability through registration. In other words, it was not known whether there was a pre-existing disability among the concerned population before the Korean Health Panel Survey, or whether the disability occurred during the survey period. Therefore, for this study, 359 people were under the category of Newly Occurred Disability from 2011 to 2018 (∼8 years) and 7,013 were without disabilities from 2008 to 2018 (11 years), finally resulting in 7,372 participants for the study. Table 2 provides detailed information on the number of new individuals with disabilities that occurred during the study period (2008–2018).

2.3. Dependent variable

The dependent variable in this study was the occurrence of new disabilities in participants (2011–2018). In the Korean Health Panel data, the presence or absence of new disabilities was reconstructed using the dichotomous method for newly occurring disabilities starting in 2010 and no disabilities from 2008 to 2018 (11 years).

TABLE 1 Korea health panel registration of persons with disabilities (63).

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
(1) Determination of disability + registration	0	0	$N = 913$ (5.10%)	$N = 944$ (5.54%)	$N = 880$ (5.54%)	$N = 839$ (5.56%)	$N = 1,073$ (5.58%)	$N = 1,039$ (5.73%)	$N = 1,020$ (5.85%)	$N = 1,039$ (6.05%)	$N = 1,045$ (6.14%)
(2) No disability	0	0	$N = 16,972$ (94.90%)	$N = 16,046$ (94.19%)	$N = 14,949$ (94.18%)	$N = 13,957$ (94.06%)	$N = 18,091$ (94.13%)	$N = 17,057$ (94.08%)	$N = 16,373$ (93.97%)	$N = 16,111$ (93.76%)	$N = 15,929$ (93.80%)
(3) Determination of disability + non-registration	0	0	0	$N = 8$ (0.05%)	$N = 11$ (0.07%)	$N = 11$ (0.07%)	$N = 14$ (0.07%)	$N = 14$ (0.08%)	$N = 10$ (0.05%)	$N = 10$ (0.06%)	$N = 8$ (0.05%)
(4) Disabled, not determined + not registered	0	0	0	$N = 37$ (0.22%)	$N = 32$ (0.02%)	$N = 32$ (0.22%)	$N = 41$ (0.21%)	$N = 20$ (0.11%)	$N = 24$ (0.13%)	$N = 24$ (0.14%)	$N = 26$ (0.15%)
Total	21,283	19,153	17,885	17,035	15,872	14,839	19,219	18,130	17,424	17,184	17,008

Source: The Korea Health Panel Survey (KHPS), 2008–2018; N, Number of participants.

TABLE 2 Newly occurred disability by years.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Disability newly occurrence	0	0	Base line	$N = 105$	$N = 20$	$N = 20$	$N = 25$	$N = 78$	$N = 34$	$N = 38$	$N = 39$	$N = 359$
Non-disabled						$N = 7,013$						$N = 7,372$

Source: (2008–2018). The Korea Health Panel Survey (KHPS); N, Number of participants.

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2.4. Independent variables

This study aimed to investigate the time effect of health-related factors on newly developed disabilities. The covariates of health-related factors that can lead to new disabilities in this study were as follows: age, sex, education level, alcohol consumption, smoking, physical activity, stress and presence of disease, number of diseases, and types of chronic diseases.

The age of the participants ranged from 4 to 106 years. Age was analyzed by grouping the participants into eight groups as follows: 19 years or younger, 20 or more but <30, 30, or more but <40, 40 or more but <50, 50 or more but <60, 60 or more but <70, 70 or more but <80, and over 80 years of age. The level of education acquisition was first measured on a 9-point Likert scale. However, in this study, it was analyzed by restructuring into five groups (e.g., elementary school or lower, middle school, high school, university, junior college, and graduate school or higher). The income level was utilized in the fifth quintile of household income.

Chronic diseases were assessed using one or more duplicates for 21 choices of various chronic diseases, allowing participants to choose from the chronic diseases they suffered from in duplicate. This study was analyzed by restructuring the presence or absence of chronic diseases, the number of chronic diseases (e.g., 0, 1, 2, and more), and types of chronic diseases (e.g., high blood pressure, diabetes, hyperlipidemia, arthritis, tuberculosis, ischemic heart disease, and cerebrovascular disease). The definition of the prevalence of chronic diseases was presented in the Korean Health Panel Survey.

Smoking status was measured using two questionnaires: one to measure current/past smoking amount and the other, secondhand smoke level. First, the amount of current/past smoking was measured on a 4-point Likert scale, with the following questions: "Do you currently smoke?" which was to be answered by choosing any of the following options: (1) never smoked, (2) used to smoke but not now, (3) occasionally smoked, (4) and now smoking daily. Second, the questionnaire on second-hand smoke asked "How much time per day do you inhale other people's cigarette smoke indoors at work or at home?" which was to be answered by choosing any one of the following options: (1) 0 h, (2) <1 h, (3) more than 1 h to <2 h, and (4) more than 2 h.

Alcohol consumption was measured as a composite of three questions: whether or not drinking, the number of drinks per year, and the average amount of alcohol consumed on an; (a) 8-point Likert Scale Alcoholism "How often have you been drinking in the past year?" The questions were as follows: (1) Never drinking in life, (2) no alcohol in the past year, (3) less than once a month, (4) once a month, (5) 2–3 times a month, (6) once a week, (7) 2 weeks to three times, and (8) almost every day; (b) the number of drinks per year; (c) average alcohol consumption using a five-point Likert scale was calculated as "How many drinks do you usually drink on a drinking day?" and is measured as follows: (1) 1–2 glasses, (2) 3–4 glasses, (3) 5–6 glasses, (4) 7–9 glasses, and (5) 10 or more glasses.

Physical activity was assessed on an 8-point Likert scale with the following response options: (1) never, (2) 1 day, (3) 2 days, (4) 3 days, (5) 4 days, (6) 5 days, (7) 6 days, and (8) 7 days (daily). It was measured as a composite of three questionnaires: vigorous physical activity, moderate physical activity, and walking. The vigorous physical activity questionnaire used the question, "In the past week, on how many days did you do more than 10 min of strenuous physical activity that caused you to be out of breath and have a significant increase in heart rate?" The response options were: running, mountaineering, soccer, basketball, jumping rope, singles tennis, squash, and so on, swimming and biking fast only, including strenuous occupational activities such as carrying heavy objects, provided that walking is only very fast walking as applicable. The questionnaire on moderate physical activity asked the question: "In the past week, on how many days did you perform moderate-to-high physical activity for more than 10 min in which you had shortness of breath and a slight increase in heart rate?" The participants could choose their responses from options such as volleyball, badminton, table tennis, doubles tennis, yoga, gymnastics, and so on, including vocational activities such as carrying light objects, swimming, and biking slowly only, but walking a little faster). Finally, the questionnaire on walking comprised the question, "In the past week, on how many days did you walk for more than 10 min?" (This includes walking slowly or at a normal speed for commuting to work, other means of transportation, and walking fast for exercise).

Stress was assessed using a 5-point Likert scale with the following options for responses: (1) never, (2) occasionally, (3) often, (4) almost always, and (5) always. It was measured as a composite of mental and physical stress and task-dependent stress, where (a) Mental/physical stress was measured with "During the past month, have you ever felt that it was difficult to handle mentally and physically in your life?" and (b) task stress with "During the past month, have you had so much to do that you forgot to do something really important?"

2.5. Statistical analyses

Pearson's χ^2 test and *t*-tests with counts and column percentages were performed for descriptive statistics. This study mainly analyzed the relationship between the occurrence of new disabilities and health-related factors and the number of chronic causes using parametric survival analysis with Weibull distribution (65). This study used the parametric model since the Cox proportional-hazards model makes minimal assumptions about the form of the reference risk function; however, this lack of assumptions hampers the prediction of risk and other related functions for a given covariate set. Therefore, the result estimation curve is not smooth and does not have

information about what happens between observed times of failure. Contrarily, the parametric model provides a good and soft prediction assuming the functional form of risk, which is used by this study as the shape of the risk does not change significantly over time.

Furthermore, we preferentially performed additional analyses of the risk estimates from models that were adjusted for age, sex, income, education, smoking, alcohol consumption, physical activity, and stress. Eight additional survival analyses were employed to determine the relationship between the presence of chronic disease and the occurrence of new disabilities according to the type of chronic disease. The specific additional factors are as follows.

Additional Model 1: Main survival analysis of health-related factors plus dichotomous chronic disease.
Additional Model 2: Main survival analysis of health-related factors plus the type of chronic disease (hypertension).
Additional Model 3: Main survival analysis of health-related factors plus the type of chronic disease (diabetes).
Additional Model 4: Main survival analysis of health-related factors plus the type of chronic disease (hyperlipidemia).
Additional Model 5: Main survival analysis of health-related factors plus the type of chronic disease (arthropathy).
Additional Model 6: Main survival analysis of health-related factors plus the type of chronic disease (tuberculosis).
Additional Model 7: Main survival analysis of health-related factors plus the type of chronic disease (ischemic heart disease).
Additional Model 8: Main survival analysis of health-related factors plus the type of chronic disease (cerebrovascular disease).

All statistical analyses were performed at a significance level of ≤ 0.05, with a confidence interval of 95%, using StataCorp Stata 15.1.

3. Results

This study was a survival analysis of the relationship between the occurrence of new disabilities and health-related factors and chronic diseases. Descriptive statistics of the study population are shown in Table 3. During the study period (2008–2018), a total of 7,372 people participated, and it was noted that 359 new disabilities occurred from 2011 to 2018; the years 2008 and 2009 had no record of disability. As of 2018, the average age was 52.14 years (SD = 21.39 years) with 3,503 (47.52%) men. It was found that 50% of the participants had chronic diseases, whereas ∼21% (1,539) and ∼16% (1,174) had two and more diseases, respectively. A total of 1,041 of three or more chronic diseases were identified. The most common chronic diseases among participants were hypertension (2,284), followed by arthropathy, hyperlipidemia (1,483), diabetes (1,006), cardiovascular disease (365), cerebrovascular disease (300), and tuberculosis (55).

3.1. Result of the main analysis

As shown in Table 4, the age of the participants were not statistically significant in developing new disabilities at all in follow-up visits, whereas sex was statistically significant (HR = 0.45, 95% CI = 0.35–0.57). The hazard of developing new disabilities was lower for female participants than for male participants. Higher education attainments were associated with lower hazard of developing new disabilities; HR estimates decreased from 1 to 0.54 to 0.38 to 0.23 to 0.06, relative to the referent group, below middle school (HR = 0.54, 95% CI = 0.38–0.77), below high school (HR = 0.38, 95% CI = 0.24–0.58), below colleges (HR = 0.23, 95% CI = 0.14–0.40), and greater graduate school (HR = 0.23, 95% CI = 0.01–0.25). It was found that the higher the income levels in the fifth quintile, the lower the risk ratio for new disability at all times of follow-up compared to the lowest level of income, which is the second level of income (HR = 0.73, 95% CI = 0.55–0.98, third level of income: HR = 0.71, 95% CI = 0.50–1.03, fourth level of income: HR = 0.47, 95% CI = 0.30–0.73, and fifth level of income: HR = 0.53, 95% CI = 0.33–0.84).

In this study, the health factors that could be related to the occurrence of new disabilities were smoking, alcohol consumption, physical activity, and stress (Figure 1). An increase in each unit in smoking was significantly associated with an increased risk of newly developing disability at all follow-up visits (HR = 1.25, 95% CI = 1.07–1.46). Similarly, an increase in each unit of alcohol consumption was linked to an increased risk of newly developing disability at all follow-up visits (HR = 0.91, 95% CI = 0.88–0.95), which was highly statistically significant ($p < 0.0001$). However, with a unit's increase in physical activity, the risk of developing a disability was significantly reduced at all follow-ups (HR = 0.97, 95% CI = 0.94–0.99).

As seen in the Figure 1, higher scores on the number of chronic diseases (valid scores = 0, 1, 2, 3, or more) represented a greater level of newly developing disability present at all follow-ups. This shows that higher ("worse") values of chronic diseases were associated with poorer prognosis of disability development (Hazard ratio estimates increase from 1 to 2.75 (95% CI = 1.70–4.44) to 3.66 (95% CI = 2.22–6.04) to 5.45 (95% CI = 3.30–9.00), relative to the referent group of the number of chronic diseases = 0). This difference was highly statistically significant ($p < 0.0001$).

TABLE 3 Descriptive statistics descriptive statistics of study sample with disability (year of 2018).

Variables	% (*N*), Mean (SD)			*p*-value
	Disability	Non-disability	Overall	
	N = 359 (4.87%)	*N* = 7,013 (95.13%)	*N* =7,372 (100%)	
Age (continuous)	65.13 (SD = 18.48)	51.47 (SD = 21.32)	52.14 (SD = 21.39)	<0.01
Age (categories)				<0.01
19 ≤	4.74% (17)	8.68% (609)	8.49% (626)	
20≤-30<	1.67% (6)	13.69% (960)	13.10% (966)	
30≤-40<	2.79% (10)	7.67% (538)	7.43% (548)	
40≤-50<	7.24% (26)	13.63% (956)	13.32% (982)	
50≤-60<	10.31% (37)	15.69% (1,100)	15.42% (1,137)	
60≤-70<	20.33% (73)	15.97% (1,120)	16.18% (1,193)	
70≤-80<	36.21% (130)	16.11% (1,130)	17.09% (1,260)	
80≤	16.71% (60)	8.56% (600)	8.95% (660)	
Male	51.81% (186)	47.30% (3,317)	47.52% (3,503)	0.10
Education				<0.01
≤ Elementary	11.70% (42)	3.14% (239)	3.81% (281)	
≤ Middle school	52.65% (189)	28.42% (1,993)	29.60% (2,182)	
≤ High school	24.79% (89)	30.20 % (2,118)	29.94% (2,207)	
≤ Colleges	10.31% (37)	29.06% (2,038)	28.15% (2,075)	
> Graduate school	0.56% (2)	8.91% (612)	8.51% (627)	
Income 5th quintile				<0.01
1st	50.14% (180)	23.04% (1,616)	24.37% (1,796)	
2nd	20.61% (74)	19.69% (1,381)	19.74% (1,455)	
3rd	13.37% (48)	18.27% (1,281)	18.03% (1,329)	
4th	7.80% (28)	19.45% (1,364)	18.88% (1,392)	
5th	7.80% (28)	19.55% (1,371)	18.98% (1,399)	
Smoking (Min = 0, Max = 3)	0.37 (SD = 0.75)	0.28 (SD = 0.69)	0.29 (SD = 0.69)	<0.05
Drinking alcohol (Min = 0, Max = 11)	2.20 (SD = 3.24)	3.21 (SD = 3.46)	3.16 (SD = 3.45)	<0.01
Physical activity (Min = 0, Max = 21)	4.79 (SD = 4.40)	5.55 (SD = 4.88)	5.52 (SD = 4.86)	<0.01
Stress (Min = 0, Max = 8)	1.05 (SD = 1.63)	0.92 (SD = 1.28)	0.92 (SD = 1.30)	0.13
Chronic disease (Yes)	84.40% (303)	49.21% (3,451)	50.92% (3,754)	<0.01
Chronic diseases				<0.01
0	15.60% (56)	50.79% (3,562)	49.08% (3,618)	
1	22.84% (82)	20.78% (1,457)	20.88% (1,539)	
2	25.35% (91)	15.44% (1,083)	15.93% (1,174)	
≥ 3	36.21% (130)	12.99% (911)	14.12% (1,041)	
Major types of chronic diseases				
Hypertension	76.69% (243)	29.10% (2,041)	30.98% (2,284)	<0.01
Diabetes	44.01% (158)	12.09% (848)	13.65% (1,006)	<0.01
Hyperlipidemia	36.21% (130)	19.29% (1,353)	20.12% (1,483)	<0.01

(Continued)

TABLE 3 (Continued)

Variables	% (*N*), Mean (SD)			*p*-value
	Disability	Non-disability	Overall	
	N = 359 (4.87%)	*N* = 7,013 (95.13%)	*N* =7,372 (100%)	
Arthropathy	39.28% (141)	27.26% (1, 912)	27.85% (2, 053)	<0.01
Tuberculosis	10.31% (37)	0.26% (18)	0.75% (55)	<0.01
Ischemic heart disease	11.98% (43)	4.59% (322)	4.95% (365)	<0.01
Cerebrovascular disease	11.98% (43)	3.66% (257)	4.07% (300)	<0.01

N = 7, 372; Source: 2008–2018 the Korea Health Panel Survey (KHPS); N, number of participants; SD, Standard deviance; Min, Minimum; Max, Maximum.

Table 5 and Figure 2 provide more specific information on chronic diseases related to newly developed disabilities during the study period. The participants with chronic diseases had an ∼4-fold increased risk of developing a new disability at all follow-ups compared to those without chronic diseases (HR = 3.81, 95% CI = 2.47–5.88). When looking at the increase in the risk of developing new disabilities due to chronic diseases, participants with tuberculosis showed the highest risk (HR = 19.87, 95% CI = 13.93–28.36), followed by diabetes (HR = 3.29, 95% CI = 2.63–4.12), hypertension (HR = 3.25, 95% CI = 2.45–4.30), cerebrovascular disease (HR = 1.71, 95% CI = 1.23–2.37), and hyperlipidemia (HR = 1.52, 95% CI = 1.21–1.91). An interesting study result was that participants with arthropathy showed a statistically significant decrease in the risk of newly occurring disability at all follow-up periods (HR = 0.65, 95% CI = 0.51–0.84).

4. Discussion

This longitudinal study confirmed the relationship between health-related factors and specific chronic diseases. Its findings can be used as a crucial foundation for establishing healthcare policies and services that can lower and prevent disability by preventing and reducing specific negative health behaviors and unhealthy behavioral factors, and alleviating chronic diseases.

Among socioeconomic factors, the relationships between sex, levels of educational attainment, income, and the occurrence of new disabilities were confirmed. Sex was statistically significant with predicting disability and death as in other study (19). As expected from previous studies, this study identified the fact that the higher the levels of education and income, the lower the risk of disability compared to the lower the education level, which was in line with the existing research (8, 9, 14, 17, 18, 20). A study of heterogeneous trajectories and associated risk factors in the development of sensory-cognitive coupling measures based on the common-cause hypothesis found that several easily identifiable socioeconomic and health-related risk factors, such as low financial status of a household, were subsequently identified as sensory-cognitive risk factors, which are reported to be an initial indicator of reduction (8). A study of the high prevalence of disability and HIV risk among urban adults with low socioeconomic status in 17 cities in the United States (14) found that adults with low socioeconomic status and heterosexual activity reported a higher prevalence of disability and differences in health, healthcare access, and risk factors. Studies investigating the prevalence and related factors of frailty and disability among older adults in China, Ghana, India, Mexico, Russia, and South Africa found that higher education and income levels were associated with lower levels of frailty and disability (17). It is believed that those above a certain level of income and a certain level of education may have more opportunities to focus more on health-related personal hygiene and health behaviors and healthcare that can reduce and eradicate chronic diseases.

Various studies have been conducted on health behaviors and choices as the causes of disability [e.g., physical activity (19), consuming fruits and vegetables less than once a day (32), current smoking/short-term ex-smoking (32), never/former/heavy alcohol drinking (32)]. A cross-sectional study of Singapore's older adult population found that a combination of factors, such as cognitive deficiency, old age, women, Malay and Indian ethnicity, lack of education, retirement or homemaker status, and the presence of chronic diseases (especially stroke, heart problems, depression, and dementia) were significant. A longitudinal study using modifiable midlife risk factors to predict the risk of physical disability during old age was also investigated, which confirmed the relationship between potentially modifiable risk factors in middle age and disability after 13 years of age (19). A study found that disability is associated with smoking, obesity, the female sex, and diabetes in predicting disability and death in the Australian population (19). A nationwide cross-national study that explored factors related to reduced mobility leading to disability in adults aged 20–89 years, found that an increase in the age of participants over 40 years was associated with a new decrease in mobility, and lifestyle habits of participants younger than 40 years, including reduced physical activity in women and being overweight, which were in turn, associated with reduced mobility at all levels (27).

In a three-city Dijon cohort study (32) it was found that unhealthy behaviors and disabilities in older adults were

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TABLE 4 Parametric survival (Weibull) regression of newly developed disability.

Covariates	HR	95% CI
Age (in years)		
19 ≤	-	-
20≤-30<	0.63	(0.24, 1.68)
30≤-40<	1.25	(0.54, 2.90)
40≤-50<	1.23	(0.61, 2.49)
50≤-60<	0.81	(0.39, 1.68)
60≤-70<	0.74	(0.36, 1.52)
70≤-80<	0.74	(0.36, 1.53)
80≤	0.49	(0.23, 1.03)
Female	0.45***	(0.35, 0.57)
Education		
≤ Elementary	-	-
≤ Middle school	0.54**	(0.38, 0.77)
≤ High school	0.38***	(0.24, 0.58)
≤ Colleges	0.23***	(0.14, 0.40)
> Graduate school	0.06***	(0.01, 0.25)
Income quintile		
1st	-	-
2nd	0.73*	(0.55, 0.98)
3rd	0.71	(0.50, 1.03)
4th	0.47***	(0.30, 0.73)
5th	0.53**	(0.33, 0.84)
Smoking	1.25**	(1.07, 1.46)
Alcohol consumption	0.91***	(0.88, 0.95)
Physical activity	0.97*	(0.94, 0.99)
Stress	1.06	(0.98, 1.15)
Number of chronic diseases		
0	-	-
1	2.75***	(1.70, 4.44)
2	3.66***	(2, 22, 6.04)
≥ 3	5.45***	(3.30, 9.00)

*P < 0.05, **P < 0.01, ***P < 0.001; 2008–2018 the Korea Health Panel Survey (KHPS); HR, hazard ratio; 95% CI, confidence interval.

examined for individual and combined associations of unhealthy lifestyle behaviors and disability risk in France. Low/moderate levels of physical activity, consumption of fruits and vegetables less than once per day, and currently smoking/short-term smoking were independently associated with an increased risk of disability, whereas no strong association was found with alcohol consumption. In that study, it was found that the risk of disability increased progressively with the number of unhealthy behaviors, which were independently associated with disability (32). Participants who engaged in all three unhealthy behaviors (e.g., less physical activity, less consuming fruit and vegetables, current smoking/short term ex-smoking) had a significantly increased risk of disability compared to those who did not. The association between unhealthy behavioral scores and disability was explained by body mass index (BMI), cognitive function, depressive symptoms, trauma, chronic conditions, cardiovascular disease, and its risk factors. An unhealthy lifestyle is associated with a greater risk of thinking disorders, which risk progressively increases with the number of unhealthy behaviors (32). Chronic conditions, depressive symptoms, trauma, and BMI partially explained this association (32). Although factors related to fruit and vegetable intake could not be analyzed in the current study, their regular intake was found to delay the onset of the disability and maintain physical health. Furthermore, drinking was not found to be a statistically significant factor in the occurrence of new disorders in this study (32). This means that the variation according to the amount and frequency of drinking among the participants in this study was too large, and most did not drink frequently. In this study, a number interpreted as a factor in the occurrence of disability was obtained, which was, however, not statistically significant.

In this study, depression and anxiety were also analyzed as factors in the development of disabilities. To investigate the relationship between baseline depressive symptoms and the development of dysfunction (ADLs: activities of daily living, IADLs: instrumental activities of daily living, mobility) at the 2-year follow-up, a prospective cohort study investigated the onset of depressive symptoms and dysfunction for 2 years. It was confirmed that the onset of IADL disorder and the onset of mobility impairment were consistently higher in the Chinese-American elderly with high levels of depression (66). Studies have identified the effects of anxiety and/or depressive disorder (ADD) and chronic somatic disorder (CSD) on disability and work disability, which are associated with significant levels of health-related disorders and work-related disorders (47). Both CSD and ADD cause significant disabilities, absenteeism, and attendance among the general population; however, the impact of ADD far exceeds that of CSD. A prior study found that CSD and ADD have synergistic effects on disability, supporting the current view that patients with physical and mental comorbidities form a severe subgroup with adverse prognoses (47).

Studies on the role of general mental and physical disorders in partial physical disorders worldwide have estimated the relationship between individuals (i.e., outcomes for individuals with disabilities), social influences (i.e., partial disorders avoided in society owing to disabilities), and mental and physical disabilities (52). Mental disorders (especially post-traumatic stress disorder, depression, and bipolar disorder) have more days of disability than physical disability. Mental and physical disabilities significantly impact partial disabilities at both

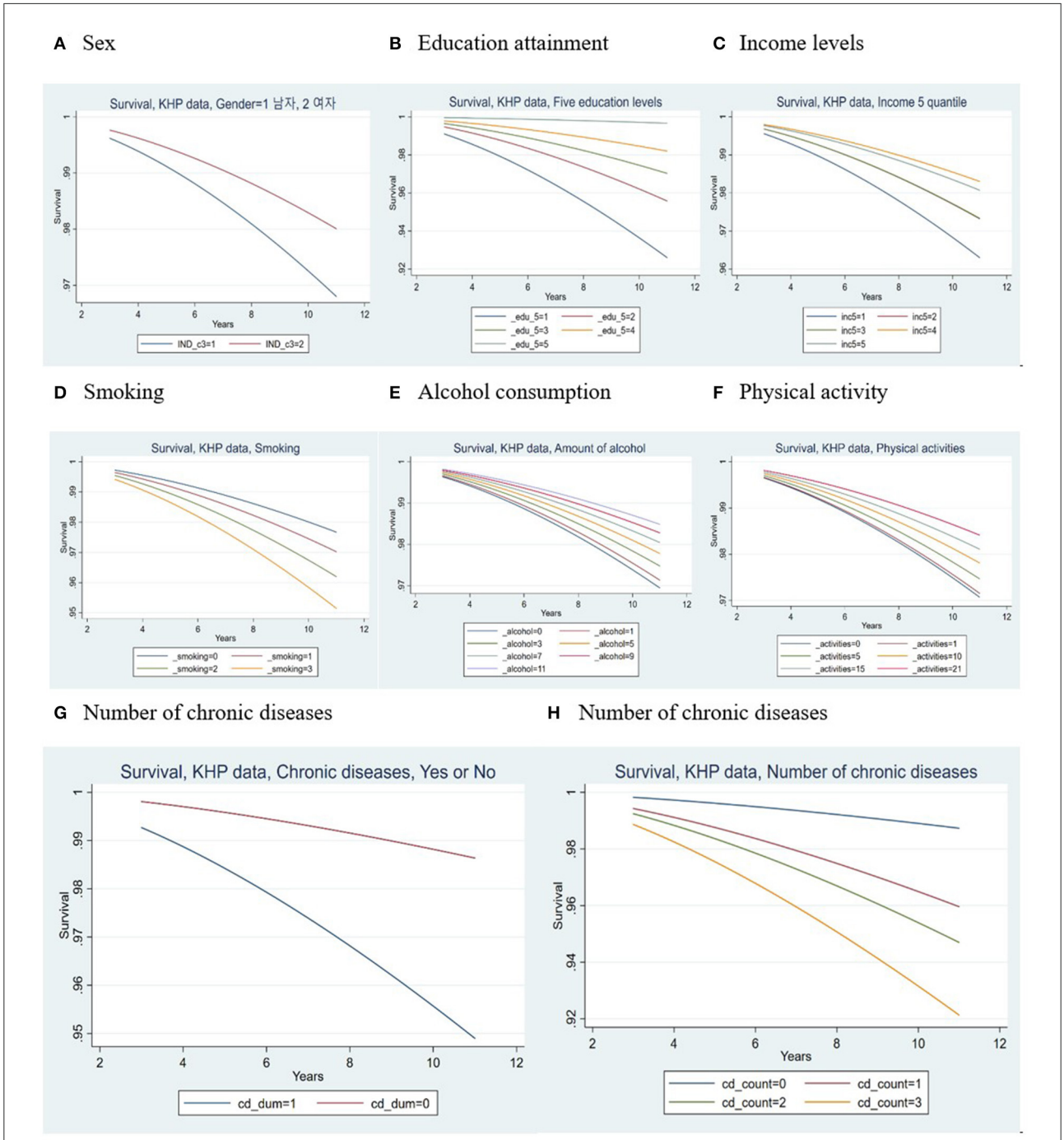

FIGURE 1
PGraph representing parametric survival (Weibull) regression of newly developed disabilities. **(A)** Sex; **(B)** Education attainment; **(C)** Income levels; **(D)** Smoking; **(E)** Alcohol consumption; **(F)** Physical activity; **(G, H)** Number of chronic diseases.

individual and social levels. It was found that physical disability had a greater effect on partial disability than on mental disability (52). It should be recognized that the occurrence of disorders, such as anxiety and depression, plays a significant role not only in physical health behaviors and chronic diseases but also in psychological aspects. Therefore, individual and social efforts are needed to manage stress and relieve depression and anxiety.

Many studies have investigated the relationship between obesity and BMI levels and chronic diseases [e.g., hypertension (22), diabetes (36)], on possible causes of disability. A study investigating the joint association of obesity and hypertension and the risk of disability in a cross-sectional setting with community-dwelling older people in Shanghai (22) showed that the risk of ADL disorder is progressively greater in obese

people with high blood pressure and IADL disorders greater in underweight individuals. Wong and colleges estimated the effects of past and future changes in obesity and diabetes prevalence in middle-aged individuals on the disability prevalence in adult Australians (36). If the percentage of obesity and diabetes observed in 2000 was as low as that observed in 1980, it was estimated that the prevalence of disabilities between the ages of 55 and 74 would have been low in 2010 (36). However, if the prevalence of obesity and diabetes were as high as the figure expected in 2025, the prevalence of disabilities would increase (36).

TABLE 5 Additional analyses of parametric survival (Weibull) regression of newly developed disability.

Chronic diseases (Yes or No)	HR	95% CI
Model 1:	3.81***	(2.47, 5.88)
Major types of chronic diseases		
Model 2: Hypertension	3.25***	(2.45, 4.30)
Model 3: Diabetes	3.29***	(2.63, 4.12)
Model 4: Hyperlipidemia	1.52***	(1.21, 1.91)
Model 5: Arthropathy	0.65**	(0.51, 0.84)
Model 6: Tuberculosis	19.87***	(13.93, 28.36)
Model 7: Ischemic heart disease	1.34	(0.96, 1.86)
Model 8: Cerebrovascular disease	1.71**	(1.23, 2.37)

*P < 0.05, **P < 0.01, ***P < 0.001; 2008–2018 the Korea Health Panel Survey (KHPS); HR, hazard ratio; 95% CI, confidence interval.

A prior study also investigated the association between type 2 diabetes and disability. It found that diabetes significantly increases the risk of disability in a study on the contribution of diabetes risk factors and complications (45). Obesity and a history of cardiovascular disease accounted for the largest proportion of the relationship between diabetes and disability, suggesting that weight and cardiovascular disease management can help control diabetes-related disorders (45).

A study investigating the association between obesity and disability development during adolescence to evaluate the longitudinal relationship between the two (26) found that the occurrence of obesity and persistent obesity during adolescence was significantly associated with an increased disability in young adulthood. In a Swedish population-based cohort study (29) that explored a potential bidirectional association between mobility impairment and obesity, it was found that obesity at baseline was associated with incident mobility disability. Bi-directional and longitudinal associations between weight and incident mobility disability were identified, along with an increased risk of developing the combination of two over time. As in other studies, diabetes and hypertension were found to significantly affect the occurrence of disabilities as also found in this study. However, while obesity or high BMI levels have been shown to affect disability in other studies, in this study, all participants with obesity or high BMI levels were normal (without any disability). Therefore, it was not possible to analyze the effects of obesity or a high BMI on the occurrence of new disorders.

A study on the relationship between chronic medical conditions caused by lack of physical activity and functional limitations over time investigated whether long-term physical

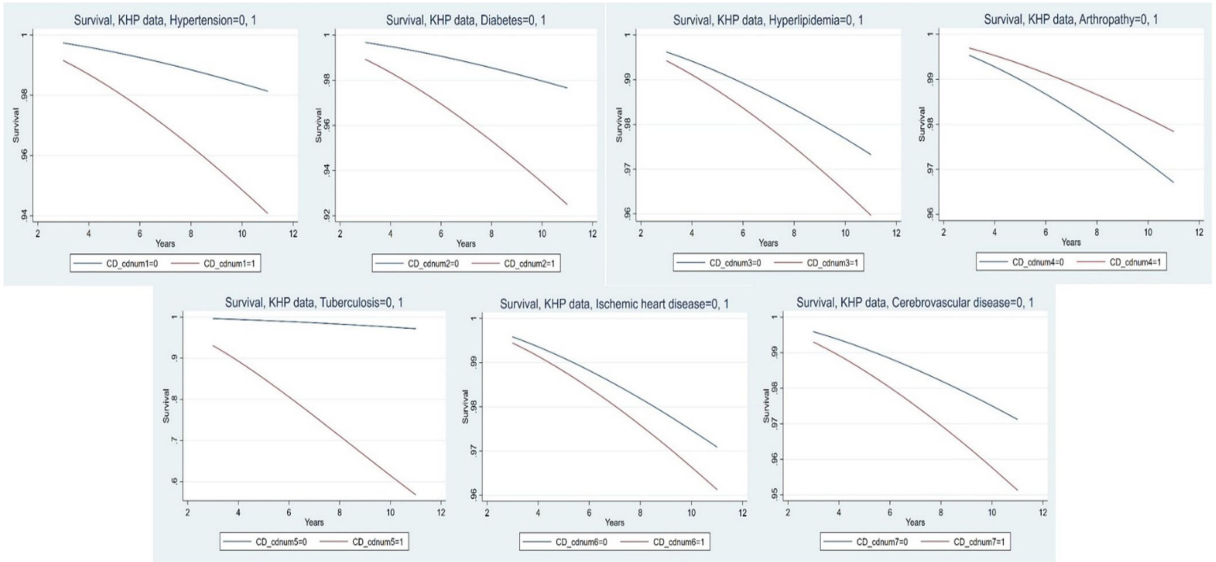

FIGURE 2
Major chronic diseases of newly developed disability.

activity could prevent functional limitations in the context of chronic disease accumulation among middle-aged and older adult populations (39). Faster development of chronic diseases and a steeper decline in activity are associated with a greater increase in functional limitations over time. Among those with faster-than-average chronic disease progression, those who remained active had a slower progression of functional restriction than those whose activity decreased more rapidly. This study, reflecting the findings of a previous study, provides evidence of an age-dependent buffering effect of activity maintenance on the longitudinal relationship between chronic conditions and functional limitations (39). Schultz-Larsen et al. (28) found that in a 14-year follow-up study of how physical activity (PA) for non-disabled older adult women and men relates to disability processes, the basic processes and effectiveness of disability development persisted permanently after adjusting for age, baseline vulnerability, and disability ratings, and low PA was independently associated with risk of accidents in males.

Leisure activity (LA) and disability trajectories of those over 11 years in Taiwan confirmed the LA trajectory and late disability of the concerned population (31). Participants in the consistently high or increasing LA trajectory group were more likely to be functionally independent, but participants in the decreasing LA subgroup had a higher risk of developing the disorder (24). The findings suggest that long-term changes in LA over time are beneficial to the physical health of older adults. A study of the osteoarthritis initiative evidence on disability and physical activity in the older population evaluated the relationship between changes in physical activity and disability in early inactive adults with or at high risk of knee osteoarthritis (34). It found that increased physical activity showed a differential relationship with improved disability scores in the late-life disability instrument limit and frequency scores (34). Increasing moderate-vigorous activity adhering to guideline levels showed the greatest decrease in developing disabilities, whereas an insufficient increase in physical activity was associated with increased disability (34).

A study on the relationship between chronic medical conditions caused by physical activity and functional limitations over time investigated whether long-term physical activity could prevent functional limitations in the context of chronic disease accumulation among middle-aged and elderly people (38). A faster accumulation of chronic disease and a steeper decline in activities are associated with a greater increase in functional limitations over time. Among those who increased their status faster than the average, those who remained active had a slower progression of functional limitation than those whose activity decreased more rapidly. This study provides evidence of an age-dependent buffering effect of activity maintenance on the longitudinal relationship between chronic conditions and functional limitations (38). Men benefit more from midlife leisure-time physical activity than women with the development of later disability, as found by the CORA Age study. As per a study, increasing physical activity reduces the risk of becoming disabled and delays the onset of disability by several years; however, it cannot be identified as influencing the severity of the disability (33, 42). Moreover, it found that men appear to benefit more from physical activity in their spare time than women (42). Various appropriate physical activities not only maintain and promote daily health but also directly or indirectly affect the occurrence of disability.

A study on the contribution of chronic disease to the burden of disability across smoking categories in middle-aged Belgian adults assessed the contribution of chronic disease to the burden of disability across smoking categories (48). The study also found an increasing trend in disability prevalence across both sexes in the smoking category. Furthermore, it found that musculoskeletal conditions have significantly contributed to the disability burden in men and women across all smoking categories (48). Other significant contributors to disabilities were depression and cardiovascular disease among non-smokers; depression, chronic respiratory disease, and diabetes in former smokers; chronic respiratory disease, cancer, and cardiovascular disease in daily light smokers; cardiovascular and chronic respiratory diseases in men; and depression and diabetes in women who smoked every day (48). In addition to the wellknown effects of smoking on mortality, our findings showed an increasing trend in disability prevalence and various contributors to the disability burden across smoking categories (48). This information could be useful in defining Belgium's disability reduction strategy from a public health perspective.

A study on the association between smoking and early retirement due to chronic disability showed the long-term effects of smoking on disability retirement in Sweden (49). Smokers are more likely to receive a (full) disability pension due to the quick onset of disabilities in them. However, in models with the sibling fixation effect, the size of the effect was reduced by more than one-third (49). The results thus highlight the importance of confounding factors, such as childhood situations or behaviors, which have not been accounted for in previous studies. It also considers the impact of disabilities on various health conditions. In relative terms, the impact is greatest for circulatory conditions and tumors (49). Although it could not be confirmed in this study, drug abuse along with smoking has a significant effect on the occurrence of disability, and illicit drugs and prescription medications can all be substances of abuse. People with disabilities may have multiple risk factors that can increase their risk of substance abuse. Smoking and drug misuse did not help maintain health and were confirmed again in this study as important factors that eventually cause disability (67).

This study also confirmed that chronic diseases were closely related to the occurrence of new disabilities. A study evaluating the incidence and determinants of physical disability in a modern and nationally representative sample of U.S. military veterans confirmed that old age, marriage/cohabitation, and

various health conditions, especially diabetes, "cardiovascular diseases," and chronic pain, are associated with an increased risk of physical disability and IADL (e.g., food and drug compliance) disability (35). A study of disability status as a precondition for chronic disease found that adults with chronic physical disabilities were more likely to have chronic diseases such as coronary heart disease, cancer, diabetes, and high blood pressure than adults without any such conditions (41). A subgroup of people with lifelong disabilities (i.e., physical, mental, intellectual/developmental, and sensory) experienced a similarly increased probability of chronic disease compared to those without restrictions. Adults with a lifetime disability were more likely to have chronic diseases than those without limitations, indicating that having a disability is likely to increase the risk of poor health (41). This distinction is important for understanding how to prevent health risks in people with disabilities. There is a need for health promotion efforts targeting people with disabilities. In a prospective cohort study, in a large cohort of older Australian women, the onset and progression of chronic diseases and disorders showed that those who reported the presence of chronic disease were more likely to experience the disability than those who died without any disability (68).

In the study on the incidence of disability and functional decline in older adults with major chronic diseases, the pattern of functional loss was investigated, and the onset and sequence of ADL disorders were compared with those without these diseases (69). Older adults with major chronic conditions were found to have a higher incidence of disability in all ADL items. People with the disorder developed chronic diseases earlier than those in the control group. The order of ADL loss, sorted by the median age of onset of disability among people with major chronic disease, is bathing, walking, getting dressed, having a bowel movement, moving, and eating (69). The sequence of losses derived for the control group was largely similar, but disability progression for patients with major chronic disease was compressed within a shorter period, and the timing gaps between adjacent disorders were smaller (69). Older adults with major non-communicable diseases face a faster and steeper decline gradient (69). Chronic care delivery programs thus must adapt to the dynamic changes in the functional status of older patients. Health interventions that help patients delay the onset of disability and optimize functional autonomy within new chronic treatment models should specifically target early loss of activities (e.g., bathing, dressing, and walking). This can help individuals avoid disabilities and retain their agility for a longer period of time in their life. The study of the effects of type 2 diabetes and high depression symptoms on the development of daily life (ADL) disability and mortality potential in older Puerto Ricans investigated the development of ADL disability and mortality activities in accordance with diabetes and high depression symptoms among adults over 60 years of age and confirmed that diabetes and high depression symptoms are the risk factors for ADL disability and mortality in older Puerto Ricans (40).

Nusselder et al. investigated the contribution of chronic diseases to disability in French men and women (46). It found that musculoskeletal disorders have caused most disabilities in both men and women, followed by cardiovascular disease in men, and in women closely followed by anxiety-depression (especially in women) (46). The high rate of incidence of musculoskeletal disorders in women reflects their higher prevalence and impact on disability. Moreover, it was noted that excluding the institutionalized population did not change the overall conclusions. The number one cause of the higher prevalence of disability in women than men is the high prevalence of moderately disabled conditions (46). While traditional disabling conditions, such as musculoskeletal disorders, are more prevalent and disabling among women, fatal diseases, such as cardiovascular disease, are also significant contributors to women and men (46). The Health and Retirement Study on Chronic Obstructive Pulmonary Disease (COPD) and Cognitive Impairment and Disability Development investigated the prevalence and cumulative incidence of disability in adults with and without COPD and the association of COPD with cognitive impairment and disability (50). Both COPD and mild cognitive impairment increase the risk for disability (50). The risks imposed by COPD are significant and comparable to or higher than those of other chronic diseases (e.g., stroke and diabetes) (50).

A systematic review of the prevalence of disability in people with cancer, cardiovascular disease (CVD), chronic respiratory disease, and/or diabetes investigated the prevalence of disabilities associated with cancer, CVD, chronic respiratory disease, and diabetes was investigated (57). The prevalence of difficulties in activities of daily living (e.g., eating, bathing, and dressing) has been reported extensively in cancer survivors, CVD patients, chronic respiratory tract patients, and diabetic patients (57). Many people with the above-mentioned conditions experience some form of disability (57). The dysfunctional trajectory estimate projected an association between diabetes, heart disease, and dementia, which may increase self-management difficulty in those afflicted by it (51). People with the potential for dementia, and diabetes, or those with diabetes and heart disease were significantly more likely to have a mild disability trajectory than those without such disability (51). People with potential for dementia were significantly more likely to have a severe disability trajectory than those with a non-disabled trajectory (51). Several chronic and cognitive conditions can be useful for health policymakers to make decisions about treatment provision and services. This study confirmed that the management of chronic diseases is very important for suppressing and delaying the occurrence of disorders.

Furthermore, it was confirmed that people with a greater number of chronic diseases were more exposed to environments

that could cause disability. Multiple chronic diseases (MCC) on activity limitation in Mexican-American older care recipients and the effect of MCC on basic ADL or IADL limitations were investigated in a prior study (30). The MCCs selected for the analysis were diabetes, hypertension, stroke, heart disease, arthritis, emphysema/COPD, cognitive impairment, depression, and cancer. Managed participants with three or more chronic conditions were more likely to have mobility, self-management, ADL, and IADL restrictions. Among the managed participants, those with arthritis, hypertension, and cognitive impairment were significantly more likely to have limited mobility than those with arthritis or hypertension alone (30). The MCC was more strongly associated with ADL and IADL restriction among management groups, especially for those with hypertension and arthritis, diabetes, cognitive impairment, or heart disease (30). A study of the association of chronic disease patterns with visual impairment and healthcare use found that individuals in the four multimorbidity groups were at a higher risk of visual impairment compared to the healthy group (43). The characteristics of the high-risk groups identified in this study may aid in the development and implementation of interventions to avoid the serious consequences of complex chronic diseases (43).

Sheridan et al. used a hierarchical model to compare respondents with multiple chronic diseases to healthy respondents, using a hierarchical model to compare unique multimorbidity combinations, future disability, and poor self-assessment health (SRH) in older adult Europeans were investigated (70). Multimorbidity combinations with high depressive symptoms were associated with an increased probability of reporting poor SRH and an increased rate of ADL-IADL disorders (70). It was more likely to be more disabling than the combination containing only the physical condition (70). These findings argue for the continued integration of mental and physical chronic diseases in the conceptualization of multimorbidity and have important implications for clinical practice and healthcare delivery.

However, in this study, the results of predicting a negative relationship with the possibility of new disorders for hip joint disease were obtained (71). Previous studies of the hip joint have been shown to make a significant contribution to the development of disability (71). Problems with the hip joint are known to cause a number of physical pain and disability. Therefore, in Korea, it is very well-recognized that the disease of the hip joint causes poor quality of life and disability throughout the body. Therefore, when Koreans suffer from hip joint disease, it seems that rapid diagnosis and correct joint management over a long period of time do not develop into a serious disease that can cause disability. Moreover, Exercise or physical activity is related to the occurrence of disability. Arthrosis causes a lack of physical activity, and this lack of physical activity is the cause of new disability in the long term (72). Due to the proportion of arthropathy patients is higher among disability developed group compared to non-developed groups in our study, it could possibly associate with controlling physical activity which would be possible pathway of developing disability in multivariate model.

The Survey on the Status of Persons with Disabilities 2020 in South Korea (3) showed ∼80% of disabled individuals over 19 years of age have chronic diseases, with an average of 2.2 chronic diseases per disabled person. The chronic diseases include high blood pressure, back and neck pain, osteoarthritis, and diabetes mellitus. In general, the physical and mental quality of life of individuals with disabilities is lower than that of the general population (73). Among the disabled, those who thought their health status was "good," accounted for 14.0%, which is less than half of the total population (32.4%) in Korea, and the rate of experiencing depression and stress in life was high (73). A total of 32.1% of people with disabilities needed support from others in their daily lives, which was slightly lower than the 33.9% reported in 2017 (73). Among them, the number of cases where "almost everything requires the support of others" was 6.2%, an increase from 2017 (5.5%) (73).

The quality of life of disabled people is significantly lower than that of non-disabled people all across the world (2, 67, 73). According to the US CDC's Report on the Related Health Status of People with Disabilities (67), people with disabilities have poor overall health, poor access to adequate healthcare, high rates of smoking, and lack of physical activity. People with disabilities need healthcare and wellness programs for the same reasons as everyone else. Being healthy essentially means staying healthy, so we can lead a full and active life. This means having the tools and information to make healthy choices and knowing how to prevent the disease. For people with disabilities, this also means knowing that the health problems associated with disability can be treated.

This study confirmed that health-related factors (e.g., drinking, smoking, physical activity, and chronic diseases) are significantly associated with the development of new. In Korea, the health care sector is rapidly changing due to the steady increase in income level, aging population, increase in chronic diseases, strengthening of medical insurance coverage, various treatment practices and medical technology development, etc., and the increase in medical expenses is expected to further accelerate. Accordingly, in order to prepare the basis for improving the policy goals of efficiency, effectiveness, and equity in the health and medical sector, and to optimize the burden on health finance, the health level and health behavior basic data on medical use and medical expenses are first used. can be used This study identified the dynamic structure of the individual's health level, which is the cause of medical expenses, in various and complex ways in the mutual process of personal factors and social, physical, and environmental factors. It is expected that scientific basic data of health care policy will be prepared through multidisciplinary

analysis and research of these series of processes and will be used as basic data for health care policy and health insurance policy establishment.

This study had the following limitations. First, this study is a longitudinal analysis of socioeconomic factors, health behaviors and choices, and chronic diseases that can factor in the occurrence of new disabilities. Nevertheless, it should be noted that it is difficult to interpret the results of this study as a causal relationship between the occurrence of new disorders. Second, this study utilized a multiple-item and self-reported measurement to assess all study variables from the participants' 1-day recollection. Therefore, this study's results may be inaccurate or biased. Furthermore, people may overestimate their health levels and behaviors due to societal bias. However, this study strengthens the literature on disability-induced factors. Factors that can cause disability can be influenced by the reciprocal processes of social, physical, and environmental factors. Third, the limited sampling region warns against the generalization of research findings to those living in more diversely populated areas (e.g., Whites, Blacks, and Hispanics). Third, as this study was conducted in the Republic of Korea, its results cannot be generalized to other countries.

5. Conclusion

In Korea, the incidence of new disabilities is gradually increasing owing to an aging population and an increase in chronic diseases. This study analyzed panel data that could be investigated in depth, including the factors affecting the occurrence of new disorders. An individual's health status and level of fitness, which is the cause of the occurrence of new disabilities, is variously and intricately intertwined in the mutual process of personal factors and social, physical, and environmental factors and has a dynamic circulation structure. Through multidisciplinary analysis and research on these processes are needed, this study can be used to prepare basic scientific data for health and medical policies to suppress and delay the occurrence of new disorders or disabilities. Accordingly, to alleviate the social and economic burden caused by the occurrence of disability, the first priority is to use medical care and spend on medical expenses in order to provide the basis for improving the policy goals of efficiency, effectiveness, and equity in the healthcare sector, and to optimize the burden on health finance. Basic data are further needed, and for establishing various healthcare and health insurance policies, but also to greatly contribute to the promotion of related academic research fields. It will aid in preventing health problems related to the occurrence of disability much in advance; maintaining and protecting health; supplementing and correcting the socioeconomic imbalance of health factors that cause disability; and reducing population, social, economic, and health-related factors. Thus, largely, it can be used as background information for the development of medical services and systems that can reduce and prevent the occurrence of disabilities in Koreans in the future.

To protect one's health the following basic steps should be followed to improve lifestyle and eliminate and reduce risk factors for disability (67): getting regular exercise, eating a healthy diet and losing weight if necessary, reducing stress, and making lifestyle changes, such as getting enough sleep. Following the above-mentioned steps can significantly lower the risk of developing chronic diseases that can lead to disorders such as heart disease, diabetes, and cancer. Thus, it can be said that maintaining an active and healthy lifestyle can considerably help avoid disabilities in the general population, which can further help minimize the risk of socioeconomic burden.

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/s.

Author contributions

TK and I-HO wrote the paper. All authors participated in the research concept of the paper and have read and agreed to the published version of the 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/fpubh.2022.1048044/full#supplementary-material

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EDITED BY
Yihui Du,
University Medical Center Groningen, Netherlands

REVIEWED BY
Hongbo Xu,
Wenzhou Medical University, China
Gustavo Andres Patino,
Oakland University William Beaumont School of Medicine, United States

*CORRESPONDENCE
Zhoufeng Wang
✉ wangzhoufeng@wchscu.cn

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Team-based learning vs. lecture-based learning in nursing: A systematic review of randomized controlled trials

Qin Zhang[1], Xiumei Tang[2], Yanjie Zhao[3] and Zhoufeng Wang[4]*

[1]Department of Postgraduate Students, West China School of Medicine, Sichuan University, Chengdu, Sichuan, China, [2]Institute of Hospital Management, West China Hospital, Sichuan University, Chengdu, Sichuan, China, [3]Department of Oncology and State Key Laboratory of Biotherapy, Cancer Center, West China Hospital, Sichuan University, Chengdu, Sichuan, China, [4]Frontiers Science Center for Disease-Related Molecular Network, Institute of Respiratory Health, West China Hospital, Sichuan University, Chengdu, Sichuan, China

Introduction: Our study aims to identify, appraise, and summarize randomized controlled trials (RCT) on the effectiveness of team-based learning (TBL) versus lecture-based learning (LBL) in nursing students.

Methods: We searched PubMed, Ovid, Embase, Cochrane, CBM, VIP, CNKI, and Wan Fang databases from inception to 22nd July 2022 to enroll RCTs that compared TBL versus LBL. The studies reporting the performance of nursing students receiving TBL pedagogy compared to those receiving traditional lecture-based learning (LBL) were to be analyzed. Scores of academic or nursing abilities were considered the primary outcome, and the results of nursing competencies, students' engagement with, behaviors, attitudes toward, experience, satisfaction, or perceptions of TBL were considered the secondary outcome. This systematic review was conducted following the guidelines of the Cochrane Reviewer's Handbook and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.

Results: A total of 1,009 participants in 10 RCTs were enrolled in this study. Of the 10 RCTs, eight studies investigated undergraduate students, one involved vocational college students, and one enrolled secondary school students. The most reported outcomes were class engagement survey toward TBL ($n = 8$); students' ability ($n = 5$), academic knowledge or performance ($n = 4$); students' experience ($n = 4$), satisfaction or perceptions of TBL ($n = 4$).

Conclusion: This review suggested that the TBL was an effective pedagogy in improving academic performance and general ability in nursing students. High-quality trials are needed, and standardized outcomes should be used.

KEYWORDS

nursing, team-based learning, lecture-based learning, education, effectiveness

Introduction

Nurses are the most significant component of the healthcare workforce and take responsibility for multiple tasks, such as providing health promotion, counseling, and education; administering medications, clinical treatment, and other health interventions; taking part in critical decision-making; and research (1). The scope and complexity of nurses' work require deliberate educational preparation (2). Several national organizations have stated that traditional education methods, using lectures and relying on student memorization, centered on the unilateral delivery of knowledge, fail to adequately prepare nurses for current healthcare realities and call for new and innovative classroom models that are learner-centered and competency-based (3). Michaelsen initially invented team-based learning (TBL) in the 1980's to cope with the dilemma between faculty resource shortage and increased students (4). Usually, TBL contains a series of steps which include preparation, readiness assurance testing, feedback, and the application of knowledge through clinical problem-solving activities (5). One significant benefit of TBL is allowing large numbers of students to experience learning with a small number of expert facilitators. Students are motivated to complete the pre-reading assigned, resulting in less content being required to be covered during class. More in-class time is allocated to problem-solving and critical thinking, promoting greater understanding and retention of knowledge (6). TBL could help develop students' professional behaviors and improve learning outcomes through active learning and student engagement, ultimately enhancing students' ability in communication, teamwork, problem-solving, and critical thinking (6).

Recently, there have been a growing number of studies regarding the effectiveness of TBL in health professions {i.e., pharmacy (7), medicine (8), midwifery (9), and nursing education (10–14). A scoping review showed that TBL had been applied in nursing education over the last decade and reported outcomes involving students' knowledge/academic performance, student experience, satisfaction, or perceptions of TBL, student engagement, behaviors/attitudes toward TBL, and teamwork, team performance/collective efficacy (15). The significant gaps identified in this scoping review were the lack of RCTs, with only 3 out of 41 included studies being RCTs [dominant study designs were evaluation of TBL in isolation (n = 19)]. Moreover, systematic reviews have been conducted on the application of TBL in nursing education. However, their results were conflicted. Some researchers (12, 16–18) found TBL was not superior to a traditional lecture, while others found excellent results regarding TBL (10, 11, 13, 14, 19, 20). Among these studies, some were quasi-experimental designs (19, 21–25), some were one-group pre- and post-test designs (26–30), and some were cross-sectional investigations (31–35).

Randomized controlled trials (RCTs) have been considered the gold standard for effective research, but numerous reviews of studies of TBL report on the relative lack of evidence based on randomized studies. The most extensive examination to date of 118 studies of TBL in health professional education reported that 57% of studies compared TBL to another educational methodology while only one was an RCT (8). A systematic review of 17 studies enrolls one RCT, two prospective crossover studies, and ten descriptive, comparative studies (36). Notwithstanding, RCTs of TBL are desirable in establishing a high level of evidence for quantitative outcomes. To our knowledge, no systematic reviews evaluated the effectiveness of TBL based on high-quality evidence. We enrolled only RCTs to compare the efficacy of TBL to lecture-based learning (LBL).

Materials and methods

Search strategy

The review was reported according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (37) and the guidelines described in the Cochrane Handbook (38). We searched PubMed, Ovid, Embase, Cochrane Library, CBM, VIP, CNKI, and WanFang databases from inception to 22nd July 2022. In addition to electronic databases, we also researched ClinicalTrials.gov and major international conferences. The reference lists of the retrieved papers were searched, and Google Scholar was used to search the gray literature. Search terms were related to nursing, education, and Team-Based Learning: the full search strategy is available in Appendix 1. No date limiters were set.

Selection criteria

Inclusion criteria followed the PICOS principles: P, the participants were nursing students; I, the intervention was TBL pedagogy; C, the control method was LBL pedagogy; O, the outcomes included all the results reported in enrolled studies. S, the study design was RCT. There was no restriction on languages or publication years. The exclusion criteria were as follows: (i) editorials, letters, commentaries, opinion papers, case studies, case reports, unpublished theses, scoping reviews, systematic reviews, and meta-analyses and papers; (ii) participants were not in-college nursing students involving nurses or setting in a hospital. (iii) Studies where the implementation of TBL was not clearly described, incomplete or modified, and distance learning courses. Reference lists of potentially eligible studies and review articles were also searched to identify additional literature. Two authors independently screened records by titles and abstracts, and the other two read full texts of potentially

eligible studies to determine eligibility. Any disagreements were resolved by consensus.

Literature screening and data extraction

Two reviewers separately extracted the essential characteristics and the statistical data from articles that meet the above requirements. Conflicts were submitted to a third reviewer, and results were produced by comparison and discussion. If necessary, detailed statistics were asked directly from the corresponding author by E-mail. Each study's characteristics were extracted *via* a pre-defined checklist, including the first author, year of publication, number of students enrolled in each group, average years, and percentage of females. More detailed information was also collected, including country, recruitment period, courses (the content of TBL, teaching period, type of students, and staff numbers), outcomes examined, and significant findings.

Quality assessment

Two authors independently rated the risk of bias in trials using the Cochrane Collaboration risk of bias tool (38). The study checked for random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessors, incomplete outcome data, selective reporting, and other biases. The following domains were assessed for each study: selection bias, performance bias, detection bias, attrition bias, and reporting bias. The risk of bias table was completed using the Review Manager (RevMan 5.4) software. Discrepancies were resolved by consensus or discussion with the other authors. The level of discrimination was then classified as high, moderate, low, or very low.

Outcomes

The outcomes were divided into four aspects: the primary product is academic scores or nursing abilities, which included examination scores, clinical performance scores, and in-class test scores. Secondary outcomes included: (i) nursing competencies: the competency can either be specific to a particular discipline or generic (such as community understanding or assessment of nursing abilities, clinical reasoning, critical thinking, problem-solving, clinical competence, communication competence, self-directed learning, and self-leadership abilities); (ii) student engagement, behaviors, or attitudes toward TBL [including the Classroom Engagement Survey (CES), learning attitude]; (iii) student experience, satisfaction or perceptions of TBL (group or peer evaluation, and students' perception of TBL).

Results

Search results

The flowchart of the literature search and study selection is shown in Figure 1. The initial search yielded 290 results, from which 174 duplicates were removed, resulting in 116 unique records. Following the eligibility criteria, 29 relevant papers were identified based on title and abstract. This resulted in the final inclusion of 10 studies for analyses in this systematic review. No additional studies of relevance were found by searching the gray literature or hand-searching the reference lists of included articles.

Baseline study characteristics

Ten studies published from 2011 to 2022 were identified for inclusion. Concerning the countries of the included studies, 4 of them were set in China (21, 39–41), 2 in Indonesia (10, 20), 2 in Korea (13, 14), one in Iran (42), and another one in Brazil (11). A total number of 1,009 participants were enrolled, and the sample size in each study ranged from a minimum of 25 (11) to a maximum of 183 (13) students. The total number of students in the TBL group was 523, and in LBL was 486. There was no difference in students' mean age or female percentage between the two groups (Table 1). Nineteen citations were excluded because participants were nurses with work experiences ($n = 7$); The study type was a comparative trial but not RCT ($n = 4$); the interventions were mixed with simulation teaching method ($n = 3$); instrument validation papers without data ($n = 3$); and the participants were interdisciplinary medicine students ($n = 2$).

For educational level, eight studies were of undergraduate students (10, 11, 13, 14, 20, 39, 41, 42), one was of vocational college students (40), and another one was of secondary school students (21). As for concerned topics, two studies featured in midwifery postpartum hemorrhage nursing (20, 21), two were about surgery nursing (11, 41), and the others were about pulmonary disease nursing (14), nursing core competency (13), emergency and intensive care nursing (40), community health care nursing (21), mental health and psychiatric disorders nursing (42), and geriatric nursing (39). TBL was implemented for varying lengths of time, ranging from a single session (11) up to courses that lasted for a whole semester (40). The number of academic staff was 2 in three studies (10, 11, 20, 40) and 3 in one study (41). In all the included studies, TBL was implemented according to the conceptual model's principles and main methodological phases. And all included studies used traditional

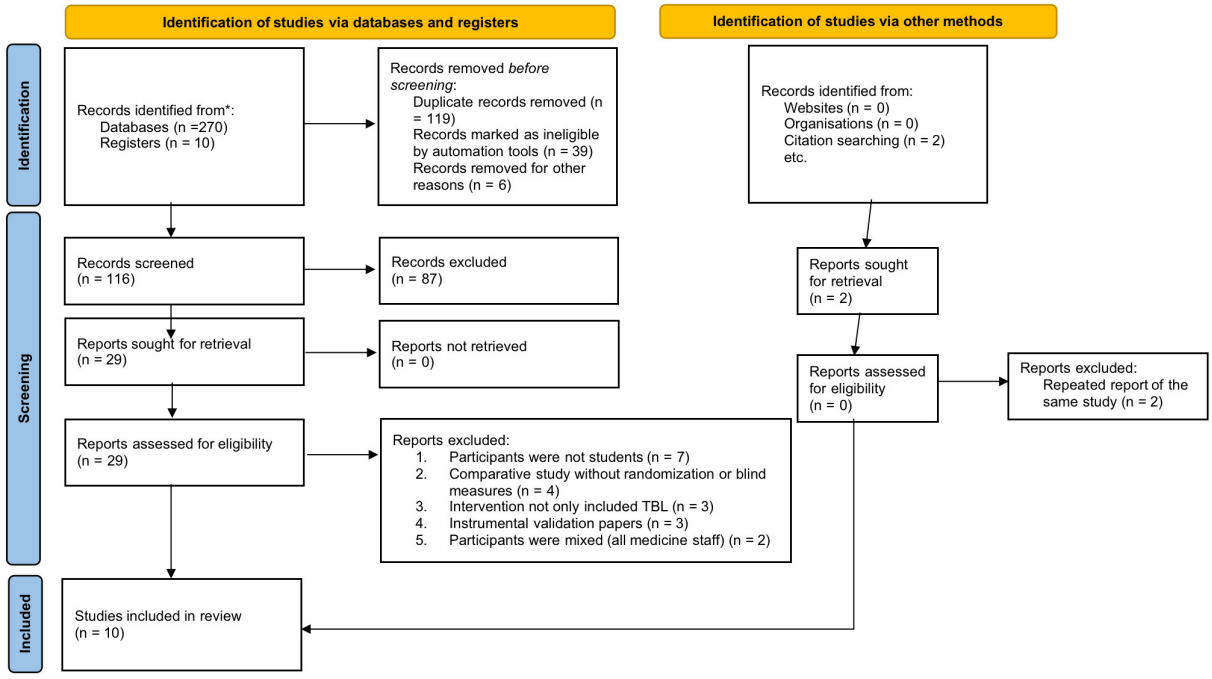

FIGURE 1
The search and selection process of included studies. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. (2021) 372:n71. doi: 10.1136/bmj.n71. For more information, visit: https://www.prisma-statement.org/.

TABLE 1 Baseline characteristics.

Study (Year)	Patients (number)		Age‡		Female gender (%)	
	TBL group	Control group	TBL group	Control group	TBL group	Control group
Yang et al. (21)	50	49	18.57 (0.51)	18.79 (0.98)	16 (32%)	44 (89.8%)
Ulfa et al. (10) A1	62	53	19.19 (0.54)	19.15 (0.50)	N/A	N/A
Ulfa et al. (20) A2	62	53	19.19 (0.54)	19.15 (0.50)	N/A	N/A
Sakamoto et al. (11)	14	11	21.80 (2.2)	20.70 (1.80)	24 (96%)	
Lee et al. (13)	95	88	23.57 (1.81)	23.48 (1.74)	89 (93.7%)	84 (94.5%)
Yang et al. (39)	55	51	22.62 (0.99)	22.57 (0.81)	43 (78.18%)	41 (80.39%)
Kim et al. (14)	32	31	22.25 (3.42)	22.39 (2.11)	4 (12.5%)	3 (9.7%)
Badiyepeymaie Jahromi et al. (42)	39	38	N/A	N/A	N/A	N/A
Xu et al. (40)	52	50	20.6 (0.9)	102 (100%)		
Han et al. (41)	62	62	N/A	N/A	51 (82.25%)	49 (79.03%)

‡ Data was presented as mean with standard error. N/A, not applicable.

lectures as the controlled measures except for one study, LBL lessons were combined with the innovative Web Quest method (42). In all the included studies, at least two different outcomes were assessed, of which at least one was measured quantitatively. Students' academic knowledge or clinical performance was most frequently mentioned and reported in 7 trials (11, 14, 20, 39–42); the students' experience, satisfaction, or perceptions of TBL were mentioned in 7 studies (11, 13, 20, 21, 39, 40, 42); generic competencies in terms of learning outcomes: instrumental competencies (i.e., problem-solving and critical thinking),

TABLE 2 Study description.

Study (Year)	Setting	Design	Recruit period	Courses			Tools/outcomes	Measure point
				Type	Period	Teachers		
Yang et al. (21)	Taiwan	Comparative study	2020.9–2021.01	Junior college level; Nursing; Community health care nursing course;	6 weeks; 180 min per week	N/A	(1) TBL scale; (2) Learning attitude; (3) Nursing competence scale;	Pre-test, post-test
Ulfa et al. (10) A1	Indonesia	Cluster RCT	2019.09–2020.03	Bachelor level; Midwifery; Post-partum hemorrhage course;	3 weeks, 90 min per week	2	(1) PPH knowledge; (2) NSSS;	Pre-test, post-test, 2\ 6\ 12 weeks post-test
Ulfa et al. (20) A2	Indonesia	Cluster RCT	2019.09–2019.11	Bachelor level; Midwifery; Clinical reasoning and classroom engagement;	3 weeks, 90 min per week	N/A	(1) Clinical reasoning ability (*via* CREST); (2) CES;	Pre-test, post-test, 2 weeks post-test; 1\ 2\ 3 weeks post-test;
Sakamoto et al. (11)	Brazil	Cluster RCT	2017	Bachelor level; Nursing; Surgery safety knowledge;	1 lession, 120 min	2	(1) Learning investigation questionnaire; (2) Self and group evaluation;	Pre-test, 1 month post-test
Lee et al. (13)	South Korea	RCT	N/A	Bachelor level; Nursing; Adult health nursing course;	3 weeks, 120 min per week	N/A	(1) Nursing core competencies (clinical competence skills; problem-solving ability; communication competence measured by Global Interpersonal Communication Competence Scale; critical-thinking ability; self-leadership by Revised Self-Leadership Questionnaire)	Pre-test, post-test
Yang et al. (39)	China	Cluster RCT	N/A	Bachelor level; Nursing; Geriatric nursing courses;	1 semester	N/A	(1) Eysenck Personality Questionnaire; (2) SDL questionnaire; CTDI-CV; (3) Critical thinking; (4) Academical scores;	Pre-test, post-test
Kim et al. (14)	South Korea	RCT	N/A	Bachelor level; Nursing; Pulmonary disease course;	3 weeks, 120 min per week	N/A	(1) Problem-solving scale for college students; (2) 20-item multiple-choice questionnaire of participants' knowledge; (3) 13-item clinical performance checklist	Pre-test, post-test
Badiyepeymaie Jahromi et al. (42)	Iran	Comparative study	2013–2014	Bachelor level; Nursing; Mental health and psychiatric disorders courses;	N/A	N/A	(1) SDLRS; (2) Buford's self-regulation questionnaire;	Pre-test, post-test
Xu et al. (40)	China	Cluster RCT	2010.09–2011.02	Vocational level; Nursing; Emergency and intensive care nursing course;	18 weeks, 180 minutes per week;	2	(1) Academic scores; (2) Clinical performance; (3) Students' satisfaction;	Post-test
Han et al. (41)	China	Cluster RCT	2008	Bachelor level; Nursing; Urology surgery nursing courses;	1 lesson, 180 min.	3	(1) Academic scores; (2) Students' perception of TBL;	Post-test

RCT, Randomized controlled trial; TBL, Team-based lecture; PPH, Postpartum hemorrhage; NSSS, Nursing student satisfaction scale; CES, Classroom engagement survey; CREST, Clinical Reasoning Evaluation Simulation Tool; CCTDI, The California Critical Thinking Dispositions Inventory; SDL, Self-directed learning; SDLRS, Guglielmino's self-directed learning readiness scale; CREST, Clinical Reasoning Evaluation Simulation Tool. N/A, not applicable.

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communication and interpersonal skills (i.e., communication skills, self-leadership, interprofessional learning skills, and teamwork) and self-directed learning (or self-learning skills) were measured in five studies (10, 13, 14, 21, 39). More detailed information on the included studies is presented in Table 2.

Knowledge or clinical performance

The results of academic knowledge or clinical performance were measured in seven studies (TBL = 316; LBL = 296), and all the trials found that the exam scores were significantly higher following the implementation of TBL compared to the scores obtained from groups that received traditional lessons (Table 3). Kim et al. (14) (TBL = 32; LBL = 31) found that students in the TBL group had higher examination scores compared to those in the LBL group (TBL group 13.6 ± 3.2 vs. LBL group 12.0 ± 1.9, $p < 0.05$) at 1-week post-test. In Ulfa et al. (20) study (TBL = 62; LBL = 53), the knowledge of postpartum hemorrhage was measured at the immediate post-test, 2, 6, and 12 weeks *post-test*, and there were significantly higher scores in the TBL group (postpartum hemorrhage (PPH) knowledge at immediate, 2, 6, and 12 weeks *post-test*, all $p < 0.001$). Sakamoto et al. (11) (TBL = 14; LBL = 11) also found higher academic scores when measured at 1-month *post-test* (TBL group 7.2 ± 0.9 vs. LBL group 7.5 ± 0.9, $p < 0.001$). In the other four studies, the measurement time of academic scores was not mentioned, but the results significantly favored the TBL group. Other than examination scores, Xu et al. (40) (TBL = 52; LBL = 50) reported the performance of clinical skills (TBL group 92.09 ± 1.79 vs. LBL group 89.86 ± 1.88, $p < 0.01$), and the results were also in favor of TBL.

Competencies

The effect of TBL on competencies was reported in six studies (TBL = 333; LBL = 310). Communication competencies were mentioned in 2 studies (n = 33; TBL = 177; LBL = 168) (13, 21). In Yang et al. (21) study (TBL = 50; LBL = 49), the results were similar between the two groups ($p = 0.077$) while Lee et al.' study (TBL = 95; LBL = 88) favored TBL (TBL group 60.62 ± 7.38 vs. LBL group 57.86 ± 6.24, $p \leq 0.007$).

The problem-solving ability scores were reported in 3 studies (TBL = 177; LBL = 168) (13, 14, 21). In Yang et al. (21) study, the results were in favor of TBL (TBL group 4.49 ± 0.51 vs. LBL group 4.18 ± 0.63, $p = 0.01$), the results were similar to Kim et al. (14) (TBL = 32; LBL = 31), which reported a higher score of problem-solving ability at 1-week *post-test* (TBL group 164.7 ± 8.4 vs. LBL group 145.2 ± 5.6, $p < 0.001$). While Lee et al.' study found similar problem-solving ability scores between TBL and LBL groups ($p = 0.431$).

The critical-thinking ability scores were reported in 2 studies (TBL = 145; LBL = 137) (13, 39), Yang et al. (39) (TBL = 55; LBL = 51) showed significantly higher critical-thinking scores (TBL group 301.18 ± 19.02 vs. LBL group 289.49 ± 28.53, $p = 0.014$) in the TBL group. However, the results in Lee et al.' study were similar between TBL and LBL groups (TBL group 101.6 ± 12.28 vs. LBL group 99.03 ± 10.18, $p = 0.127$).

The self-directed learning scores were reported in 2 studies (TBL = 55; LBL = 51) (39, 42), Yang et al. (39) showed significantly higher self-directed learning ability scores (TBL group 74.19 ± 7.92 vs. LBL group 69.76 ± 8.40, $p = 0.006$). Badiyepeymaie Jahromi et al. (42) (TBL = 39; LBL = 38) also found similar results (TBL group 43.24 vs. LBL group 39.3, $p < 0.01$).

Moreover, Yang et al. (21) divided nursing competencies into community understanding, community assessment, collaborative tendency, and problem-solving tendency, which all benefit the TBL group (all $p < 0.05$). Ulfa et al. (10) reported results measured at multiple time points and found TBL improved students' clinical reasoning scores right after the test as well as at 2 weeks *post-test* (immediately after the test: TBL group 38.0 ± 7.36 vs. LBL group 28.55 ± 5.89, $p < 0.001$; 2 weeks after the test: TBL group 34.0 ± 7.32 vs. LBL group 23.81 ± 6.16, $p < 0.001$). Lee et al.' study reported five subscales of clinical competence skills, including scores of self-leaderships, problem-solving ability, communication competence, and critical thinking ability. Among them, positive responses favoring the TBL group were evidenced in three outcomes (clinical competence skills, $p = 0.014$; self-leadership, $p = 0.025$; and communication competence, $p = 0.007$).

Student engagement, attitudes, satisfaction, or perceptions toward TBL

Student engagement or attitudes toward TBL were reported in 2 studies (TBL = 89; LBL = 87) (21). Yang et al. (21) reported positive attitudes toward TBL and high levels of student engagement (TBL group 4.51 ± 0.54 vs. LBL group 4.28 ± 0.57, $p = 0.039$).

Student satisfaction or perceptions of TBL were reported in 4 studies (TBL = 190; LBL = 176) (11, 20, 40, 41). Xu et al. (40) reported high levels of satisfaction (TBL group 108.44 ± 9.97 vs. LBL group 103.72 ± 6.68, $p < 0.01$). Ulfa et al. (20) also revealed that TBL was associated with a higher level of nursing students' satisfaction (TBL group 34.19 ± 3.26 vs. LBL group 19.81 ± 1.94, $p < 0.01$). About the perception of TBL, Sakamoto et al. (11) (TBL = 14; LBL = 11) found positive results while this benefit ($p < 0.02$) disappeared 1 month later. Han et al. (41) (TBL = 62; LBL = 62) reported a majority of students had a positive perception of TBL (82.3–93.5%).

TABLE 3 The outcomes of included studies.

Study (years)	Results				Conclusions
	Outcomes	TBL	Control	*P*-values	
Yang et al. (21)	(1) Learning attitude: Team efficacy	4.51 ± 0.54	4.28 ± 0.57	$p = 0.039$*	The results demonstrated that TBL improved participants' community understanding and enhanced their skills for assessing and fulfilling community needs. The experimental and control groups differed significantly in their TBL performance, learning attitude, and nursing competencies. The performance of those who engaged in TBL was higher than that of those who engaged in TBL on all community issues. TBL appears to be a more effective method than TL in terms of achieving nursing students' knowledge objectives.
	Collaborative learning	4.49 ± 0.57	4.19 ± 0.60	$p = 0.012$*	
	Learning attitude	4.56 ± 0.39	4.50 ± 0.46	$p = 0.516$	
	Individual self-efficacy	4.21 ± 0.37	4.21 ± 0.65	$p = 0.994$	
	(2) Nursing abilities: Community understanding	4.04 ± 0.40	3.04 ± 0.46	$p < 0.001$*	
	Community assessment	3.96 ± 0.57	3.33 ± 0.70	$p < 0.001$*	
	(3) TBL scale: Collaborative tendency	4.44 ± 0.51	4.23 ± 0.52	$p < 0.05$*	
	Communicative tendency	4.55 ± 0.48	4.35 ± 0.62	$p = 0.077$	
	Problem-solving tendency	4.49 ± 0.51	4.18 ± 0.63	$p = 0.01$*	
Ulfa et al. (10) A1	(1) PPH knowledge at immediate post-test;	85.20 (7.58)	72.49 (14.74)	$p < 0.001$*	The findings showed that TBL is an effective active learning strategy to improve knowledge of PPH of Indonesian midwifery students before clinical practice exposure. TBL also resulted in a higher learning satisfaction score in the intervention group.
	PPH knowledge at 2 weeks post-test;	83.59 (10.08)	71.73 (13.96)	$p < 0.001$*	
	PPH knowledge at 6 weeks post-test;	80.36 (9.07)	69.09 (17.16)	$p < 0.001$*	
	PPH knowledge at 12 weeks post-test;	85.95 (6.16)	77.02 (12.79)	$p < 0.001$*	
	(2) SNNN	34.19 ± 3.26	19.81 ± 1.94	$p < 0.001$*	
	(3) Willingness to be a midwife	57 (91.9%)	41 (77.4%)	$p = 0.03$*	
Ulfa et al. (20) A2	(1) Clinical reasoning scores after test	38.0 (7.36)	28.55 (5.89)	$p < 0.001$*	The mean clinical reasoning on postpartum hemorrhage scores were significantly higher in the TBL students than in the LBL students at post-test ($p < 0.001$; Cohen's d = 1.41) and 2 weeks post-test ($p < 0.001$; Cohen's d = 1.50). The CES showed a significantly higher in the intervention group than in the control group.
	(2) Clinical reasoning scores at 2 weeks	34.0 (7.32)	23.81 (6.16)	$p < 0.001$*	
	(3) CES at 1 week post-test	33.53 ± 2.83	22.34 ± 2.50	$p < 0.001$*	
	(4) CES at 2 weeks post-test	33.61 ± 2.96	21.68 ± 1.62	$p < 0.001$*	
	(5) CES at 3 weeks post-test	34.03 ± 2.98	20.94 ± 1.77	$p < 0.001$*	
Sakamoto et al. (11)	(1) Group evaluation at pre-test	29.4 ± 6.4	19.9 ± 4.1	$p < 0.02$*	Students' apprehension of knowledge in the TBL group was significantly higher compared to the control group ($p < 0.002$) by considering the pre-test results. After 30 days, there was no significant difference between groups. The experience with the methodology was considered positive among students.
	(1) Group evaluation at 1 month post-test	30.6 ± 4	27.6 ± 5.9	Not significant	
	(2) Peer evaluation (Team evaluation, Self-evaluation)	No total score			
	(3) TBL questionnaire	No total score			
	(3) Academical scores at 1 month post-test	7.2 ± 0.9	7.5 ± 0.9	$p < 0.001$*	

(Continued)

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TABLE 3 (Continued)

Study (years)	Results				Conclusions
	Outcomes	TBL	Control	*P*-values	
Lee et al. (13)	(1) Clinical competence skills	75.28 ± 9.26	72.18 ± 7.51	$p = 0.014$*	The TBL group achieved significantly higher scores for clinical competence skills, communication competence, critical thinking ability, and self-leadership post-test than pre-test, whereas the LBL group achieved significantly higher scores for clinical competence skills and critical thinking ability at post-test than pre-test. After the intervention, the experimental group had significantly better clinical competence skills, communication competence, and self-leadership than the control group.
	(2) Self-leadership	132.01 ± 17.1	126.73 ± 14.36	$p = 0.025$*	
	(3) Problem-solving ability	74.76 ± 20.84	72.53 ± 16.89	$p = 0.431$	
	(4) Communication competence	60.62 ± 7.38	57.86 ± 6.24	$p = 0.007$*	
	(5) Critical thinking ability	101.6 ± 12.28	99.03 ± 10.18	$p = 0.127$	
	(6) Students' preference	2.10%	3.40%	Not significant	
Yang et al. (39)	(1) Self-directed learning ability (overall scores)	74.19 ± 7.92	69.76 ± 8.40	$p = 0.006$*	The application of TBL in the teaching of geriatric nursing courses for undergraduate nursing can improve students' autonomous learning ability and critical thinking ability.
	(2) Critical-thinking ability	301.18 ± 19.02	289.49 ± 28.53	$p = 0.014$*	
	(3) Academical scores	80.61 ± 4.88	78.47 ± 6.52	$p < 0.05$*	
Kim et al. (14)	(1) Problem solving ability at 1 week post-test	164.7 ± 8.4	145.2 ± 5.6	$p < 0.001$*	This study found that TBL improved problem-solving ability, knowledge, and clinical performance in third-year Korean nursing students. Active team discussions and feedback strategies used in TBL were effective in obtaining positive learning outcomes.
	(2) Knowledge at 1 week post-test	13.6 ± 3.2	12.0 ± 1.9	$p < 0.05$*	
	(3) Clinical performance at 1 week post-test	22.3 ± 2.6	16.3 ± 1.0	$p < 0.001$*	
Badiyepeymaie Jahromi et al. (42)	(1) Total self-directed learning (rank rate)	43.24	39.3	$p < 0.01$*	Participants' self- directed (self-management) and self-regulated learning differed between the two groups ($p = 0.04$ and $p = 0.01$, respectively). However, the scores related to learning (students' final scores) were higher in the WebQuest approach than in team-based learning
	Self-control (rank rate)	37.33	35.72	$p = 0.73$	
	Self-engagement (rank rate)	34.57	38.33	$p = 0.76$	
	Self-management (rank rate)	31.11	40.75	$p = 0.04$*	
	(2) Final examination scores	59.08 ± 6.43	67.08 ± 6.43	$p = 0.02$*	
Xu et al. (40)	(1) Academic knowledge scores	84.83 ± 5.62	81.70 ± 8.21	$p = 0.028$*	Students in TBL class were better than those in LBL class on practical skills assessment, theory test scores and analysis quiz. The feedback of teaching content, teacher factors,examination and evaluation, and the overall satisfaction in study group were better than those in LBL group.
	(2) Clinical performance	92.09 ± 1.79	89.86 ± 1.88	$p < 0.01$*	
	(3) Students' satisfaction	108.44 ± 9.97	103.72 ± 6.68	$p < 0.01$*	
Han et al. (41)	(1) Academic knowledge scores	84.7 ± 2.6	78.9 ± 3.2	$p < 0.01$*	The application of the TBL teaching model improved students' academic knowledge scores, and most of the students were in favor of TBL using in class.
	(2) Students' perception of TBL (Percentage)	82.3–93.5%			

*: $p < 0.05$.

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Risk of bias

The risk of performance bias (blinding of participants and personnel) and detection bias (blinding of outcome assessment) were considered as the domain most frequently rated as a source of bias, with five at unclear risk and five at low risk. The risk of selection bias (allocation concealment) was unclear in 4 studies and low in 6 studies. The selection bias (random sequence generation) was unclear in 3 studies and low in 7 studies. The attrition bias was high in one study, and the other bias was low (Table 4). Therefore, the overall risk of bias was considered moderate in the performance bias and detection domains and low in the other four domains.

Discussion

Summary of the evidence

This systematic review confirmed the effectiveness of TBL in different settings. TBL could significantly improve students' academic knowledge, clinical performance, competency skills, satisfaction, perceptions, and attitudes. The first significant advantage of this review was that we only enrolled RCT design trials because previous reviews of studies of TBL report on the relative lack of randomized controlled studies (9, 15, 43).

TBL usually contains 4 phases: (i) teacher-guided pre-class preparatory learning; (ii) assessing mastery of core knowledge through the Individual Readiness Assurance Process' (iRAT) and Team Readiness Assurance Process (tRAT) test; (iii) application of newly acquired knowledge to significant authentic problems through application exercises and then students defend their decisions with evidence in a discussion led by the teacher; (iv) provide a peer evaluation of team members (6).

Knowledge or clinical performance

All the reported studies were in favor of TBL with regard to academic scores. Our findings were like the previous reviews (15, 43). Possible reasons are that students in the TBL group prepared themselves with an out-of-class study by reading the iRAT material before the in-class sessions. The use of tests at the beginning of the in-class sessions also improved students' independent learning and acquisition of prior knowledge while students in the traditional classroom were passive learners and were not prepared individually to study early before attending the in-class sessions. And tRAT can stimulate students to attain a better understanding of the materials, especially poorly prepared students, as they can learn from their peers through sharing and discussion.

Moreover, Ulfa et al. (20) found that TBL could retain the nursing knowledge gained and had higher scores than the

TABLE 4 Methodologic quality assessment of included studies (RCT).

Study (year)	Random sequence generation (Selection bias)	Allocation concealment (Selection bias)	Blinding of participants and personnel (Performance bias)	Blinding of outcome assessment (Detection bias)	Incomplete outcome data (Attrition bias)	Other bias
Yang et al. (21)	Unclear	Unclear	Unclear	Unclear	Low risk	Low risk
Ulfa et al. (10) A1	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Ulfa et al. (20) A2	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Sakamoto et al. (11)	Low risk	Low risk	Low risk	Low risk	High risk	Low risk
Lee et al. (13)	Low risk	Low risk	Low risk	Unclear	Low risk	Low risk
Yang et al. (39)	Low risk	Low risk	Low risk	Unclear	Low risk	Low risk
Kim et al. (14)	Low risk	Low risk	Unclear	Low risk	Low risk	Low risk
Badiyepeymaie Jahromi et al. (42)	Unclear	Unclear	Unclear	Unclear	Low risk	Low risk
Xu et al. (40)	Low risk	Unclear	Unclear	Unclear	Low risk	Low risk
Han et al. (41)	Unclear	Unclear	Unclear	Low risk	Low risk	Low risk

LBL group at long-term periods, and the results of Sakamoto et al. (11) also enhanced the conclusion. Possible reasons were that the tRAT in TBL could improve students' understanding of a clinical topic, as real conditions enhanced their memory and sharpened their understanding. The integration of learning strategies such as TBL and clinical practice could yield a comprehensive understanding, and such integration can help with knowledge retention.

Competencies

Nursing students are required to gain the knowledge, techniques, and attitudes necessary to effectively solve problems that are presented in various situations. Therefore, core competencies were indeed needed, which included not only the perceptual capabilities that enable successful problem-solving in clinical situations but also widely applicable and complex capabilities such as healthy attitudes toward the self, others, and the organization as well as practical social skills (13).

Our study confirmed the effectiveness of TBL in promoting the core competencies of nursing education. The results were similar to previous studies (15, 43). Of note, the tools used for competency evaluation varied from trial to trial. In Yang et al. study (21), they used a self-designed nursing competence scale that reflected the ability of the community to understand or assess nursing skills. In Ulfa et al. (10) study, Clinical Reasoning Evaluation Simulation Tool (CREST) was applied, which comprehensively assesses the student's ability to solve cases and the student's analytical thinking in linking signs and symptoms to appropriate diagnoses and actions according to the scenario provided. Clinical reasoning is the ability to integrate knowledge and critical thinking. In the TBL process, the application exercise applies the topic concepts, stimulating students to use their knowledge and to think critically, therefore enhancing their clinical reasoning ability. In Lee et al. (13) study, they used five tools that measured the abilities of clinical competence, problem-solving, communication competence, critical thinking, and self-leadership. Self-directed learning ability was another kind of nursing core competency, which was presented as mean and standard deviation in the Yang et al. (39) study and rank scale in Badiyepeymaie Jahromi et al. study (42). The reason why TBL effectively developed the core competencies (including self-leadership, clinical competence skills, problem-solving ability, and critical thinking ability) was that TBL could assist nursing students in integrating and applying their knowledge previously learned in courses now studied in advance. In addition, TBL enhances communication competence *via* interactions among team members. Implementing TBL has obvious cost saving implications since facilitator requirements could be reduced by approximately half whereas provided equivalent clinical expertise at the same time (6). It should be noted, however, the difficulties instructors have when implemented TBL, which were pre-class preparation, academic expertise requirements, as well as in-class control (5, 43).

Student engagement, attitudes, satisfaction

Our study found that the nursing students in TBL group had better performance in student engagement with class and had a most positive attitude and higher satisfaction levels with their experiences. The classroom engagement survey (CES) was used to assess student engagement in class in Ulfa et al. study (20). CES contained eight items, scored on a five-point Likert scale, with total scores ranging from 5 to 40. The reason for the enhanced engagement ability in the TBL group is that students were asked to have a discussion, in contrast to the traditional lectures wherein the students only learned passively. Therefore, the TBL activities showed how TBL could promote classroom engagement. In Yang et al. study (21), learning attitude was reported, and the results of collaborative learning and team efficacy favored TBL while learning attitude and individual self-efficacy were similar. Possible reasons were that TBL works mainly on the collaborative ability to improve. Though we found relatively high satisfaction regarding TBL implementation, the willingness of students was negative when promoting TBL since they have to do more pre-class practice, which increases their burdens (41). Nevertheless, instructors also found TBL hard to promote, as it requires instructors to develop IRAT/GRAT questions and teaching scenarios and imposes additional academic burdens on staff.

Therefore, for TBL to be more actively adopted in nursing education, instructors will require a suitable curriculum and sufficient time to prepare the management of TBL sessions. And students should be provided with sufficient information on the TBL processes in addition to learning content and sufficient time to conduct self-directed learning in advance using pre-class assignments or regular class sessions.

Limitations

The limitations of this study were as follows: first, most of the included RCTs reported different outcomes or the same outcome with different measurement tools. Therefore, quantitative results were absent. Second, though standard TBL procedures were applied in class, the durations of TBL varied a lot, which may influence the results. Third, we include only RCT studies to gain high-quality and reliable results. However, RCT cannot fully measure the full array of learner responses.

Conclusion

In general, this review suggested that the TBL was an effective pedagogy in improving academic performance and general ability in nursing students despite the education level regarding the current reports. However, most of the RCTs were of moderate quality. High-quality trials are in need, and standard outcomes should be applied. We recommend that future studies focused on TBL also include qualitative and observational components to ascertain a broader array of behavioral, cognitive, and motivational outcomes more deeply and perhaps to elucidate the mechanism (s) by which TBL effects student learning.

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

QZ and ZW designed the conception of the manuscript. XT and YZ drafted the original version of the manuscript and drew the figures and tables. XT, QZ, and ZW revised the final version of the manuscript. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1044014/full#supplementary-material

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EDITED BY
Yihui Du,
University Medical Center Groningen, Netherlands

REVIEWED BY
Sandheep Sugathan,
Quest International University Perak, Malaysia
Xiaomin Song,
BeiGene, China

*CORRESPONDENCE
Eman Alsaleh
✉ ealsaleh@philadelphia.edu.jo

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Prevalence of physical activity levels and perceived benefits of and barriers to physical activity among Jordanian patients with coronary heart disease: A cross-sectional study

Eman Alsaleh[1]* and Faris Baniyasin[2]

[1]School of Nursing, Philadelphia University, Amman, Jordan, [2]Department of Physiotherapy, Philadelphia University, Amman, Jordan

Background: Many studies published in other countries have identified certain perceived benefits of and barriers to physical activity among patients with coronary heart disease. Nevertheless, there is no data about the issue relating to Jordanian patients with coronary heart disease.

Objective: This study aimed to describe the prevalence of levels of physical activity, the benefits of and barriers to physical activity as perceived by Jordanian patients with coronary heart disease, and the relationship between physical activity and perceived benefits of and barriers to physical activity. In addition, it focused on examining the influence of selected sociodemographic and health characteristics on physical activity and the perceived benefits of and barriers to physical activity.

Methods: A cross-sectional design was performed on a sample of 400 patients with coronary heart disease. They were given a list of perceived benefits of and barriers to physical activity and asked to what extent they disagreed or agreed with each.

Results: Jordanian patients with coronary heart disease perceived various benefits of and barriers to physical activity. Most of these benefits were physiologically related (average mean = 5.7, SD = 0.7). The most substantial barriers to physical activity as perceived by the patients were "feeling anxiety," "not enough time," "lack of interest," "bad weather," and "feeling of being uncomfortable." Sociodemographic and health characteristics that significantly influenced perceived barriers to physical activity were age, gender, health perception, chest pain frequency, education, job, caring responsibilities, ability to travel alone, smoking, and previous and current physical activity behavior.

Conclusion: This study demonstrates that patients with coronary heart disease have perceived physiological benefits of physical activity and have perceived motivational, physical health, and environmental barriers to physical activity, which is significant in developing intervention strategies that aim to

maximize patients' participation in physical activity and overcome barriers to physical activity.

KEYWORDS

physical activity, perceived benefits, perceived barriers, coronary heart disease, prevalence

Introduction

Physical activity is essential in preventing and treating coronary heart disease (CHD) (1–3). The standard PA recommendation for patients with CHD is ≥150 min of moderate-intensity PA per week (4). Evidence suggests that PA markedly contributes to a decrease in modifiable CHD risk factors such as increased BP and overweight (5–7), which are associated with a decrease in the negative impact of CHD on physical health. Significantly, many reviews have reported a decrease in BP among patients with CHD who participated in the recommended level of PA (8–10). In addition, PA increases PA capacity and improves endothelial function, facilitating coronary blood flow through the vasodilatation mechanism (11). These physiological effects of PA have been shown to lower relapse rates, symptoms, and cardiac ischemia after cardiac events among patients with CHD (12–14). Furthermore, PA has been demonstrated to improve quality of life (QoL) and decrease anxiety and depression among patients with CHD (15, 16), even though it has been documented that the benefit from physical activity among patients with CHD is more significant than that of PA among healthy subjects without CHD (12).

Although the significant benefits of PA are well-known in the treatment of CHD, the vast majority of patients with CHD do not achieve PA following recommendations, even when they engage in a structured PA program or cardiac rehabilitation program (17). The performance of regular PA is considered one of the principal challenges in the success of the secondary prevention regimen of these patients through modifications in their lifestyle habits (17, 18). In Jordan, it was found that only 34.8% of patients with CHD performed regular walking exercises (19).

The contributing factors of low performance and adherence to PA that have been consistently reported in the literature include individual characteristics, such as motivation and self-efficacy. Perceived barriers to PA, such as time and access, and characteristics of PA behavior, such as PA type, intensity, and duration (20). In addition, the lack of PA programs and the referral of patients with CHD to these programs, as well as inaccessible PA programs, are significant reasons for low adherence to PA among patients with CHD (21, 22). Patients with CHD in Jordan do not receive structured secondary prevention or cardiac rehabilitation programs. Usually, these patients are provided with verbal or written advice about their disease and lifestyle modifications, including the performance of PA. This information is usually provided during the hospital stay or after discharge during patients' attendance at the clinic for follow-up care, which could hinder patients from performing PA and may be considered a principal barrier to performing PA. Although many studies have examined the relationships between perceived benefits of and barriers and PA participation in western societies, little information is available about how Jordanian patients with CHD perceive the benefits of and barriers to PA. In addition, how these constructs explain the patients' decision to PA is rarely examined.

The health promotion model (HPM) identifies perceived benefits of and barriers to action as influencing factors for health-promoting behavior, such as participation in PA. In this model, health-promoting behavior is the desired outcome (23, 24). The benefits of PA are defined as "a person's perceptions of positive and enjoyable outcomes of this behavior" (25). PA has perceived benefits that are incorporated into physiological, psychological, social, and body image benefits (26, 27). The motivational value of perceived benefits is based on previous personal experiences or outcomes observed by others. Perceived barriers to PA are linked to individuals' challenges when performing PA as an inconvenience, expense, difficulty, time, physical condition, or environmental barrier. The perceived barriers influence the initiation of a new PA or reduce an individual's commitment and adherence to the current PA. Systematic reviews have demonstrated an inverse relationship between the perception and number of barriers and levels of PA among patients with CHD (28).

The significant aspect of the success of programs and interventions that aim to promote PA in patients with CHD is the recognition of factors that limit participation in these programs (29). Information about the benefits of and barriers to PA perceived by Jordanian patients with CHD can inform nurses and healthcare providers, which helps develop an appropriate individualized approach based on patients' perception of PA benefits of and barriers to maximize patient participation in overcoming barriers to PA. These interventions could significantly assist patients with CHD in obtaining the beneficial effects of PA to improve their health, prevent complications, and thus decrease the mortality of CHD.

This study aimed to describe the prevalence of PA levels in patients with CHD and the benefits of and barriers to PA

as perceived by Jordanian patients with CH and describe the relationship between perceived benefits of and barriers to PA and the participation of these patients in PA. Furthermore, it aimed to describe the influence of selected sociodemographic and health characteristics on perceived benefits of and barriers to PA and the participation of PA.

Methodology

First, approval from the Institutional Review Board at King Abdullah University Hospital (KAUH) and Jordan University Hospital administration to interview the patients was secured. Then, the researcher reviewed patients' files who visited the cardiac clinic between 1 July 2019 and 1 October 2019. Those who met the inclusion criteria were identified and invited to participate in the study. A structured interview technique to collect the required data was used.

The sample size was 400 patients with CHD, determined based on the prevalence of PA among CHD in the previous study by determining 40% at a 95% CI, 5% margin of error and adding 37 patients considering dropouts among participants (30). Two university hospitals in Jordan were included to recruit the participants. The inclusion criteria were patients diagnosed with angina or myocardial infarction (MI) at least 4 months before data collection, who were mentally competent, and who were aged 30–70 years. Exclusion criteria included any physical or psychological condition that affected patients' participation in the study.

Physical activity

The participants were administered the International Physical Activity Questionnaire (IPAQ), which assesses physical activity status. The instrument asks questions about the performance of 30 min of moderate-intensity activity 5 days per week (150 min per week) or a combination of walking and moderate-intensity activities amounting to a minimum of at least 600 METs-minutes/week. The IPAQ is a reliable and valid tool for assessing PA (reliability: kappa 0.67–0.73; Spearman's rho 0.67–0.81).

Benefits of and barriers to PA questionnaire

Since there are no clinical tools for the reliable evaluation of perceived benefits of and barriers to PA among patients with CHD, the researcher developed a scale consisting of two lists of perceived benefits of and barriers to PA based on the literature. The first list contains 22 items that reflect PA's physical, psychological, and social benefits. The second list contains 41 items that reflect PA's physical, psychological, social, and environmental barriers. The response for each item was on a 6-point Likert scale ranging from (1) strongly disagree to (6) strongly agree. In addition, two open-ended questions asked participants' opinions about additional benefits of and barriers to PA. Items of perceived benefits and barriers demonstrated a high level of internal consistency; Cronbach's alpha was calculated: 0.87 for perceived benefits of PA and 0.92 for perceived barriers to PA. Also, test-retest reliability for the total instrument was 0.89 for the Exercise Benefits Scale and 0.77 for the Exercise Barriers Scale.

To evaluate the clarity and understandability of the perceived benefits of and barriers to PA, the researcher interviewed ten patients with CHD in the cardiac clinics of both hospitals before starting data collection using structured interviews. The patients were six males and four females. In total, seven patients were diagnosed with MI, and three patients with angina. Results showed that all participants reported that all items were clear, understandable, and at the level of the patient's comprehension.

Statistical analysis

Descriptive statistical analysis was used to describe the sample. The Pearson correlation was used to describe the relationship between the benefits of and barriers to PA and the continuously measured sociodemographic and health characteristics. The same test was used to describe the relationship between individual and health characteristics, and PA was measured continuously. In addition, the *t*-test, chi-square test, and Fisher's exact test were used to examine differences in perceived benefits of and barriers to PA and individual and health characteristics concerning PA behavior that was measured on a continuous and dichotomous level. A one-way analysis of variance was used to compare the means of two or more independent groups.

Results

Demographic and health characteristics of the study

The participants were 400 patients with CHD between 36 and 70 years old, with two-thirds being male. There were no significant differences between the two groups (Tables 1, 2).

Physical activity prevalence

According to the International Physical Activity Questionnaire (IPAQ), 24% of the patients are classified

TABLE 1 Sociodemographic characteristics of the sample ($n = 400$).

Variables		Frequency	%	Mean	(SD)	Range
Age				54.34	(8.94)	36–70
Gender	Male	259	64.7			
	Female	141	35.3			
Marital status	Married	341	85.3			
	Single	40	10			
	Widowed	12	3			
	Divorced	7	1.7			
Living status	With family	350	87.5			
	Alone	50	12.5			
Education level	Illiterate	46	11.5			
	Primary	74	18.5			
	Secondary	100	25.0			
	College	150	37.5			
	Baccalaureate	24	6			
	Graduate studies	6	1.5			
Occupation	Yes	240	60			
	No	100	25			
	Retired	60	15			
Type of Job	Laborers	195	48.7			
	Office work	45	11.3			
	No work	160	40			
Income per month				321	(125)	1–1,500
Caring responsibilities	Yes	211	52.7			
	No	189	47.3			

SD, standard deviation.

as physically active. According to IPAQ, participants were recognized as physically active when they met the PA guidelines of 30 min of moderate-intensity activity 5 days/week (150 min/week) or engaged in a combination of walking and moderate-intensity activities for a minimum of at least 600 METs-min/week.

The influence of patient's characteristics on PA status

It was found that male respondents and laborers were significantly more engaged in PA than females and office workers. Also, there was a statistically significant difference between physically active and non-physically active participants regarding physical activity advice, chest pain frequency, and perception of health. Patients with weak PA advice perceive their health as poor and have more chest pain frequency. They also have low PA levels. However, other factors such as marital status and smoking showed no statistically significant relationship with PA engagement (Tables 3, 4).

The association between PA status and perceived benefits of and barriers to PA

There was a significant difference between physically active and non-physically active participants regarding PA's psychological and social benefits. Physically active patients perceive these benefits more than non-physically active patients. However, no significant difference between the two groups of patients was detected as regards the physical benefits of PA, such as "preventing overweight," "decreasing the risk of coronary artery disease," and "decreasing triglycerides."

TABLE 2 Health characteristics of the sample ($n = 400$).

Variables		Frequency	%	Mean	(SD)	Range
Medical diagnosis	Angina	223	55.7			
	MI	177	44.3			
Treatment	Invasive intervention(PTCA, stent)	121	30.3			
	Open heart surgery	60	15			
	Medications	219	54.7			
Chronic diseases	Yes	188	47.0			
	No	212	53.0			
Diseases type	DM	90	22.5			
	HTN	65	16.2			
	DM and HTN	33	08.3			
PA advice	No advice	165	28.0			
	Weak	160	32.0			
	Moderate	20	30.0			
	Strong	55	10.0			
PA status	Physically active	75	18.7			
	Non physically active	325	81.3			
Perception of health	Excellent	49	12.3			
	Very good	52	13			
	Good	140	35			
	Weak	159	39.7			
Ability to travel alone	Yes	188	47			
	No	212	53			
Chest pain frequency				5	0.77	0–5
Smoking	Yes	180	45			
	No	220	55			

SD, standard deviation; MI, myocardial infarction; PTCA, percutaneous transluminal coronary angioplasty; DM, diabetes mellitus; HTN, hypertension; PA, Physical activity.

Improving knowledge about the physiological benefits of PA is an essential element that should be included in the PA programs provided to patients with CHD.

While regarding perceived barriers items about performing PA, physically active and non-physically active participants were significantly different regarding most of the perceived barriers to PA. Physically active patients exhibited fewer physical, psychological, social, and environmental barriers to the perception of PA than non-physically active participants.

Perceived benefits of and barriers to PA

Most of the benefits perceived by patients with CHD were physiological benefits, such as "improves health" ($M = 5.81$, SD $= 0.53$) "improves body muscle's flexibility" ($M = 5.79$, SD $= 0.52$), "improves strength" ($M = 5.69$, SD $= 0.58$), "prevents overweight" ($M = 5.74$, SD $= 0.75$), "decreases risk of CHD" ($M = 5.71$, SD $= 0.16$), "decreases triglycerides" ($M = 5.70$, SD $= 0.72$), and "improves cardiovascular fitness" ($M = 5.68$, SD $= 0.69$) (Table 5).

The biggest barriers to PA as perceived by the patients were as follows: "feeling with anxiety" ($M = 4.53$, SD $= 1.81$), "not enough time" ($M = 4.47$, SD $= 1.93$), "feeling of being too lazy" ($M = 4.42$, SD $= 1.81$), "busy at work" ($M = 4.36$, SD $= 1.86$), "lack of interest" ($M = 4.34$, SD $= 1.97$), "bad weather" ($M = 4.32$, SD $= 1.92$), "don't like to do PA alone" ($M = 4.16$, SD $= 1.98$), "not frequently seeing others perform PA" ($M = 3.93$, SD $= 2.05$), "feeling of being uncomfortable" ($M = 3.84$, SD $= 1.76$), and "PA causes shortness of breath" ($M = 3.83$, SD $= 1.82$) (Table 6).

TABLE 3 Association between participants' sociodemographic characteristics and physical activity.

	Physically active				Test	*p*
	Yes	(%)	No	(%)		
Age mean (SD)	29.70	8.20	29.04	7.54	– 0.750†	0.454
INCOME PER MONTH						
Gender						
Male	191	47.7	68	17	7.393!	0.007*
Female	62	15.5	79	19.8		
Occupation						
Yes	122	30.5	118	29.5	0.010!	0.921
No	88	22	72	18		
Occupation type						
Office workers	24	6	21	5.3		0.365
Laborers	112	28	83	20.7		0.002*
Marital status						
Married	190	47.5	151	37.7	0.327#	0.955
Single	22	5.5	18	4.5		
Widow	6	1.5	6	1.6		
Divorce	4	1	3	0.7		
Smoking						
No	100	25	120	30	0.155!	0.694
Yes	96	24	84	21		
Living status						
Alone	22	5.5	28	7		
With family	178	44.5	172	43		
Educational level					0.231	0.623
Illiterate	22	5.5	24	6		
Primary	34	8.5	40	10		
Secondary	52	13	48	12		
College	77	19.2	73	18.3		
Baccalaureate	14	3.5	10	2.5		
Graduate	4	1	2	0.5		
Ability to travel alone						
Yes	90	22.5	98	24.5	12.177#	0.007*
No	108	27	104	26		
Caring responsibilities					0.241!	0.324
Yes	108	27	103	25.7		
No	98	24.6	91	22.7		

† Independent *t*-test.
! Chi-square test.
Fisher's exact test.
* Significant *p*-value of <0.05.
SD, standard deviation.

TABLE 4 Association between participants' health characteristics and physical activity.

	Physically active				Test	*p*
	Yes	(%)	No	(%)		
Perception of health						
Excellent	74	18.5	25	6.2	0.189#	0.910
Very good	76	19	26	6.5		0.004
Good	24	6	66	16.5		
Weak	27	6.75	82	20.5		
Chest pain frequency mean (SD)	24.80	3.99	26.26	4.34	3.132†	0.002*
Chronic diseases						
Yes	98	24.5	90	22.5	12.177#	0.007*
No	104	26	108	27		
PA advice						
No advice	81	20.2	84	21		
Weak	79	19.7	81	20.4		
Moderate	11	2.7	9	2.3		
Strong	28	7	27	6.7		

† Independent *t*-test.
# Fisher's exact test.
* Significant *p*-value of <0.05.
SD, standard deviation.
PA, physical activity.

The influence of sociodemographic and health characteristics on perceived benefits of PA among Jordanian patients with CHD

Job type significantly influenced the perceived benefits of "decreasing triglycerides" and "giving enjoyment." Laborer workers perceived this PA benefits more than office workers. Physically active participants perceived all physiological benefits more than non-physically active participants.

The influence of sociodemographic and health characteristics on perceived barriers to PA

This study demonstrated the importance of sociodemographic and health characteristics of patients with CHD in influencing their perception of barriers to PA, including (1) health perception, (2) chest pain, (3) the ability to travel alone, (4) education, (5) age, (6) gender, (7) caring responsibilities, (8) job status, (9) current PA behavior, (10) smoking, and (1) PA advice. Health perception had a significant negative relationship with the barriers "feeling with anxiety" and "PA causes shortness of breath". Patients with poor health were more likely to perceive "feeling with anxiety" and "PA causes shortness of breath" as solid barriers to PA. Chest pain frequency had a significant positive relationship with "feeling uncomfortable" barriers and "PA causes shortness of breath." Participants who reported more chest pain frequency were more likely to perceive "feeling uncomfortable" and "PA causes shortness of breath" as solid barriers to PA. Age is negatively related to "busy at work" and "not enough time" barriers. Young participants were more likely to perceive "busy at work" and "not enough time" as solid barriers to PA. No significant relationships with other barriers were found.

Females, illiterate, patients who could not travel alone, smokers, and non-regular physically active perceived "feeling uncomfortable" and "not enough time" as barriers to PA more than their counterparts. Illiterates and individuals who are unable to travel alone perceived "feeling anxiety" as a barrier to PA more than educated individuals who were able to travel alone. Illiterate and non-regular physically active perceived "PA causes shortness of breath" as a barrier to PA more than educated and regular physically active. Individuals who had

TABLE 5 Benefits of physical activity as perceived by Jordanian patients with CHD.

Perceived benefits of PA	Mean	(SD)	PA		Test	*P*
			Yes	No		
1- Improves health	5.81	0.53	5.84	5.04	4.23	0.050*
2- Improves flexibility	5.79	0.52	5.82	4.53	5.12	<0.001*
3- Prevents overweight	5.74	0.75	5.44	5.13	5.06	0.32
4- Decreases risk of coronary artery disease	5.71	0.16	5.08	5.02	12.32.25	0.17
5- Decreases triglycerides	5.7	0.72	5.88	5.71	4.56	0.18
6- Improves strength	5.69	0.58	5.91	5.14	4.25	0.23
7- Improves cardiovascular fitness	5.68	0.69	4.56	3.97	3.65	0.002
8- Gives enjoyment	5.55	0.77	4.86	3.88	0.58	0.013*
9- Keeps the weight from increasing	5.55	0.78	5.23	5.14	0.89	0.15
10- Helps to feel better in general	5.52	0.75	4.36	3.37	1.26	0.023*
11- Helps to feel more energetic	5.5	0.77	5.25	4.54	3.58	0.010*
12- Prevents hypertension and DM	5.49	0.86	5.12	4.88	4.69	0.020*
13- Gives confidence in self	5.44	0.8	4.56	3.25	3.62	0.021*
14- Decreases hospital admission	5.43	1.08	4.23	3.983.69	4.89	0.006*
15- Improves self-image	5.41	0.84	4.88	4.02	1.58	0.028*
16- Provides a way to meet a people	5.4	0.85	4.21	4.25	2.56	0.010*
17- Lifts the spirit and causes happiness	5.4	0.84	4.95	3.86	3.58	0.011*
18- Improves the appearance	5.39	0.89	3.88	3.1	1.49	0.368
19- Helps to cope better with stress	5.39	0.82	4.13	3.65	2.78	0.002*
20- Improves attitude toward life	5.31	0.94	4.63	3.43	3.25	0.001*
21- Helps to relax	5.12	1.02	5.02	3.09	2.89	0.002*
22- Decreases mortality	4.17	1.66	5.28			0.001*

Test: Independent *t*-test.
*Significant *p*-value of <0.05.
SD, standard deviation; PA, physical activity.

caring responsibilities perceived being busy at work as a barrier to PA more than those who were not employed and did not have caring responsibilities. Office workers perceived bad weather as a barrier to PA more than laborers workers. PA advice had a significant negative relationship with barriers such as "not enough time," "feeling of being uncomfortable," "lack of advice," and "feeling too boring."

Discussion

Although physical activity is widely reported as a principal factor in improving health, it is viewed as a significant challenge for patients with CHD worldwide. This study found that patients were mainly physically inactive (76%). Perceived benefits of and barriers to PA are vital elements influencing PA participation in this study. The physically active patients perceive more benefits of and fewer barriers to PA than non-physically participants. However, no study documented the perceived benefits of and barriers to PA in Jordan among patients with CHD.

All participants in this study reported substantial perceived benefits of PA that were mainly physiological benefits rather than psychosocial benefits, which may be related to the influence of media components that focus on the physiological benefits of PA. Therefore, patients may have more information about the physiological benefits of PA than the psychological benefits of PA. However, physically active patients perceived the physiological and psychosocial benefits of PA more than those who were not regularly physically active. In addition, it may be related that most participants (76%) were not regularly physically active to experience PA's physiological and psychosocial benefits. The role of healthcare providers in

TABLE 6 Barriers to physical activity as perceived by Jordanian patients with CHD.

Perceived benefits of PA	M	(SD)	PA		Test	*P*
			Yes	No		
1- Feeling with anxiety	4.53	1.817	4.67	4.33	3.85	0.05*
2- Not enough time	4.47	1.936	4.85	4.36	3.98	0.001*
3- Feeling like being too lazy	4.42	1.810	4.10	4.96	3.25	0.024*
4- Busy at work	4.36	1.861	4.28	4.11	3.54	0.120
5- Lack of interest	4.34	1.971	4.21	4.28	3.55	0.250
6- Bad weather	4.32	1.922	4.02	4.12	3.54	0.250
7- Do does not like to do PA alone	4.16	1.983	3.45	3.52	3.78	0.240
8- Not frequently seeing others doing PA	3.93	2.056	3.85	3.01	3.25	0.002*
9- Feeling of being uncomfortable	3.84	1.768	3.92	3.21	3.65	0.002*
10- PA causes shortness of breath	3.83	1.826	3.80	3.58	3.88	0.1022
11- Being hot and sweaty	3.76	1.776	3.85	3.74	3.58	0.203
12- No convenient places	3.61	1.999	3.56	3.64	3.21	0.130
13- Fearing of pain in joints or back	3.58	1.810	3.21	3.89	3.52	0.210
14- Feeling too boring	3.57	1.671	3.05	3.55	2.32	0.140
15- Lack of advice	3.57	1.760	3.52	3.25	3.35	0.210
16- PA causes sore muscles	3.51	1.642	3.74	3.45	3.68	0.710
17- Fearing of falling	3.51	1.744	3.42	3.54	3.25	0.410
18- Not seeing friends PA	3.49	1.720	3.65	3.58	3.25	0.280
19- Presence of caregiving duties in the home	3.36	1.851	3.51	3.78	3.52	0.250
20- Lack of confidence	3.34	1.719	3.21	3.41	3.52	0.230
21- Feeling too uncoordinated	3.32	1.614	3.12	3.42	2.85	0.520
22- Having a negative feeling	3.25	1.610	3.10	3.30	2.56	0.120
23- No convenient sidewalks	3.21	1.860	3.18	3.24	2.87	0.410
24- Feeling with depression	3.17	1.551	3.10	3.24	3.74	0.240
25- Family does not encourage doing PA	3.15	1.666	3.12	3.18	3.41	0.210
26- No presence of natural places	3.14	1.886	3.12	3.16	3.54	0.240
27- PA causes dizziness	3.10	1.806	3.8	3.12	3.54	0.180
29- PA causes abnormal BP	2.96	1.699	2.58	2.54	3.21	0.680
30- Fearing of looking silly or funny when the PA	2.75	1.755	2.47	2.54	3.25	0.780
31- Restriction of social norms	2.74	1.790	2.71	2.81	2.58	0.250
32- No presence of enjoyable scenery	2.67	1.793	2.47	2.84	2.74	0.880
33- No presence of street light	2.67	1.531	3.25	2.52	2.54	0.250
34- Having trouble with vision	2.53	1.678	2.54	2.5 8	2.45	0.620
35- Having muscles weakness	2.53	1.306	2.54	2.68	2.41	0.580
36- No feeling safe walking on the street	2.49	1.636	2.37	2.47	2.74	0.250
37- Presence of heavy traffics	2.44	1.540	2.47	2.52	2.84	0.020
38- PA is too expensive	2.37	1.542	2.34	2.40	2.14	0.410
40- PA causes difficulty in sleeping	2.22	1.418	2.18	2.26	2.410	0.170
41- Presence of attended dogs on streets	2.20	1.497	2.14	2.15	2.45	0.160

Test: Independent *t*-test.
*Significant *p*-value of <0.05.
SD, standard deviation; M, Mean; PA, physical activity.

reinforcing the knowledge about the impact of physical and psychosocial benefits of PA is a crucial step to be considered in PA programs.

A predominance of perceived psychosocial barriers to PA was observed were "anxiety," "lack of interest," "feeling of being too lazy," "do not like to do PA alone," and "not frequently seeing others doing PA." These barriers were also identified in Myers and Roth's studies (26). Anxiety reflects that patients may feel anxious about fear from fatigue or other symptoms when they do PA because they have CHD. "Feeling of being too lazy" reflects that patients have low motivation and negative feelings that inhibit them from PA.

Not enough time was reported in the present study. As such, the need for positive reinforcement and reassurance from healthcare providers who advocate physical activity in CHD is considered necessary to overcome this barrier. The time barrier reflects that individuals are busy at work, which is also perceived as a barrier to PA. It reflects no motivation to do PA because time barriers and busyness at work excuse more than the cause of not participating in PA, which is congruent with the findings of other studies, which showed that time was the most significant barrier perceived by cardiac patients. It is the most prevalent self-reported reason for dropout from supervised clinical and community PA programs (31, 32). Motivation to do PA is predominately prescribed as a barrier to doing PA among adult people (32). The barriers of "lack of interest," "do not like to do PA alone," and "not frequently seeing others doing PA" reflect the importance of social support in motivating patients to use PA. It was demonstrated that social support was significantly associated with physical activity behavior (33–35). The physical barriers PA perceived were "feeling of being uncomfortable" and "shortness of breath". This finding is congruent with the literature, which showed that physical problems were one of the most significant barriers to PA (36–38). Physical barriers that are frequently reported in the literature include fatigue (36), being uncomfortable (37, 38), lacking energy, and shortness of breath (38). After CHD, patients may feel too weak for PA and fear that PA will lead to cardiac events. This feeling may decrease their self-efficacy with PA. Decreased self-efficacy may increase the perception of physical barriers. On the contrary, regular PA could improve self-efficacy to perform PA; thus, the barrier of low self-efficacy may be diminished (39). The result that could be noticed in this study is that the participants who are not physically active perceive a lack of confidence as a barrier to PA more than the physically active participants. The environmental concern of bad weather was strongly perceived as a significant barrier to PA. This finding is congruent with other findings (18). Since some patients have no unique places or closed centers to perform PA as alternatives to brisk outdoor walking, bad weather may be an essential concern. In addition, bad weather seems to reflect no attention and excuses more than barriers to PA.

Conclusion

This study demonstrated that most patients with CHD (74%) are non-physically active. The challenge of participation in PA was linked to perceived benefits and barriers to PA. The patients in this study perceived various physiological and psychosocial benefits of PA. Also, Jordanian patients with CHD perceived different physical and psychosocial barriers to PA. In addition, it was found that the sociodemographic and health characteristics of the patients with CHD influenced their participation in PA and their perception of PA benefits and barriers to PA. The factors such as age, gender, health perception, chest pain frequency, education, job, PA advice, caring responsibilities, ability to travel alone, smoking, and current PA behavior were considered. It seems that different groups with samples perceived different barriers to PA. The findings of this study suggest that it may be valuable to replicate this study using a more significant and heterogeneous randomly selected sample to increase the generalization of the findings. The findings also suggest investigating barriers to PA as perceived by different groups of people (young, old, female, and educated people) to identify their specific perceived barriers to PA and investigate selected interventions that are appropriate to decrease barriers to PA among patients with CHD. Also, the findings of this study indicate the need for an influential role for nurses and other health team members who provide care to patients with CHD in Jordanian hospitals and clinics. This role should consider the benefits of and barriers to PA and the influence of sociodemographic and health characteristics on perceived barriers to PA in their interventions to motivate the patients to participate in regular PA.

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 Institutional Review Board at King Abdullah University Hospital (KAUH) and Jordan University Hospital Administration. The patients/participants provided their written informed consent to participate in this study.

Author contributions

EA planned the research, carried out the data collection, analyzed the data, and wrote the manuscript. FB reviewed the

paper for publication. All authors contributed to the article and approved the submitted version.

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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EDITED BY
Yihui Du,
University Medical Center Groningen, Netherlands

REVIEWED BY
Sidra Abbas,
COMSATS University Islamabad, Sahiwal Campus, Pakistan

*CORRESPONDENCE
Xiaowei Liu
✉ xiaoweiliu312@163.com

†These authors have contributed equally to this work

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Application of artificial intelligence to the public health education

Xueyan Wang[1†], Xiujing He[1†], Jiawei Wei[2], Jianping Liu[3], Yuanxi Li[1] and Xiaowei Liu[1*]

[1]Laboratory of Integrative Medicine, Clinical Research Center for Breast, State Key Laboratory of Biotherapy, West China Hospital, Sichuan University, Chengdu, Sichuan, China, [2]Research Center for Nano-Biomaterials, Analytical and Testing Center, Sichuan University, Chengdu, Sichuan, China, [3]The First People's Hospital of Yibin, Yibin, Sichuan, China

With the global outbreak of coronavirus disease 2019 (COVID-19), public health has received unprecedented attention. The cultivation of emergency and compound professionals is the general trend through public health education. However, current public health education is limited to traditional teaching models that struggle to balance theory and practice. Fortunately, the development of artificial intelligence (AI) has entered the stage of intelligent cognition. The introduction of AI in education has opened a new era of computer-assisted education, which brought new possibilities for teaching and learning in public health education. AI-based on big data not only provides abundant resources for public health research and management but also brings convenience for students to obtain public health data and information, which is conducive to the construction of introductory professional courses for students. In this review, we elaborated on the current status and limitations of public health education, summarized the application of AI in public health practice, and further proposed a framework for how to integrate AI into public health education curriculum. With the rapid technological advancements, we believe that AI will revolutionize the education paradigm of public health and help respond to public health emergencies.

KEYWORDS

artificial intelligence, algorithm, big data, public health, education, curriculum

Introduction

The severe acute respiratory syndrome (SARS) outbreak in 2003 was the first epidemic that seriously impacted public health. In addition, H1N1 influenza, Ebola virus, polio, Zika virus, and coronavirus disease 2019 (COVID-19) have been declared public health emergencies of international concern by the World Health Organization, which have also led to the severe global public health crises (1, 2). Today, the COVID-19 pandemic and monkeypox outbreak in 2022 are still sweeping across the globe (3, 4), causing heavy burdens on healthcare, lives, and the world economy (5, 6). All of these reinforce the importance of strengthening public health systems. Public health workforce fighting on the front line is committed to disease control and provides effective health protection and health care for the health system. However, shortages of these

professionals have severely hampered the implementation of preventive measures in this outbreak as expected, pointing to the demand to train more public health professionals through education (7, 8). Furthermore, the urgent needs of all sectors of society for public health emergency systems, vaccine development, and training of medical personnel have also highlighted the importance of medical education, especially public health education.

Recently, public health education remains largely based on traditional curricula with globally similar core competencies (9, 10). Public health education is generally based on five fundamental and core discipline areas including biostatistics, epidemiology, environmental health sciences, social and behavioral sciences, and health policy management (11, 12). To assess the educational content and educational competencies, interdisciplinary and cross-cutting subjects, such as communication and informatics, leadership, diversity and culture, professionalism, public health biology, program planning, and system thinking, are also incorporated into the public health curriculum of most schools (13). Moreover, core competencies for addressing public health practice challenges have also been incorporated into the certification criteria. Even so, a large part of the training process is focuses on absorbing much information as possible and learning how to apply that knowledge in practice, which is still based on memory (14). Additionally, under the traditional education model, the quality of teaching largely depends on the level of teachers. However, excellent teachers not only need long-term training but also are in short supply. Traditional coursework and book knowledge alone can hardly equip students to address real-world public health challenges (9, 14, 15). Teaching cannot keep up with new technologies and teaching content. Therefore, the optimization of public health education and the cultivation of public health professionals become the top priorities in the context of current epidemics (11, 16).

As an emerging technology in the twenty-first century, artificial intelligence (AI) has already penetrated various fields, including the economy, science, healthcare, and medicine, and has become an important driving force for their future development (17, 18). Nowadays, thousands of mature AI applications, such as virtual assistants, autonomous vehicles, facial recognition, and medical diagnosis, have been developed to solve problems in specific industries or institutions (19–21). AI-based financial applications such as Mint or Turbo Tax act as personal financial assistance, collecting personal data and providing sound financial advice (22, 23). Automakers such as Toyota, Volvo, and Tesla use AI techniques to train computers to think like humans to avoid accidents while driving in any environment (24). Facial recognition based on computer vision is the most common field of AI. Facial recognition technology on mobile phones and laptops can replace pin numbers and passwords, securing an individual's data (25). AI-based machine and deep learning models are being used to detect diseases such as skin, liver, heart, and Alzheimer's (26, 27). Among them, the recurrent neural network and the feed-forward neural network have achieved 97.59 and 100% in the diagnosis of liver disease hepatitis virus, respectively (28). Moreover, AI has been successfully applied to healthy education and clinical training, including ophthalmology (29), radiology (30), physical (31), and residency training (32). For example, Fang et al. (32) have applied AI-based pathologic myopia identification system in the ophthalmology residency training and achieved satisfactory training efficiency. All of these have shown the powerful potential of AI.

Notably, AI also plays a pivotal role in the transformation of education. Recently, AI has shown the potential to address educational challenges and innovate teaching-learning practices, enhancing teaching quality. AI-based intelligent tutoring systems that can identify and respond to students' knowledge gaps, personalized virtual tutors, two-way intelligent feedback between teachers and students, data mining, and the execution of mundane tasks will contribute to improving the quality of education (33). Here, we reviewed the fundamentals of AI, focused on the application of AI in public health practice, offered reasonable curriculum recommendations for introducing AI in public health education, and further discussed the prospect of AI in public health.

Fundamentals of artificial intelligence

Broadly, AI refers to the process by which computers and machines simulate human behavior, including perception, learning, inferencing, analysis, and decision-making, to perform tasks through data processing and pattern recognition (34–36). AI includes multiple subsets or subfields, of which machine learning, deep learning, neural networks, computer vision, and robotics are the five main subfields of AI. Machine learning and deep learning are two major subfields that are often mentioned in AI (37, 38). Machine learning enables computers to learn autonomously by analyzing training data and experience without explicit programming. Furthermore, its performance improves with time. Machine learning algorithms include the supervised type that needs a training dataset containing input data and expected output and the unsupervised type that the data itself learns instead of the training datasets (39, 40). Recently, multiple complex problems in areas, such as finance, healthcare, and manufacturing, have been well-addressed through machine learning (41–43). Deep learning has aroused much concern due to its remarkable success in computer vision, speech recognition, and self-driving cars. Deep learning is not only another subset of AI but also a subset of machine learning. It belongs to a class of machine learning algorithms that use multiple layers of artificial neural networks

as an architecture for data representation learning (40, 44–46). A deep neural network trained on more than 37,000 head computed tomography scans of intracranial hemorrhage evaluated 9,500 unseen cases, reducing the time to diagnose intracranial hemorrhage in new outpatient clinics by 96% with 84% accuracy (47). Neural networks are often used to create software that can imitate human learning and decision-making (46). Artificial neural networks composed of many interconnected processing nodes or neurons have the ability to learn to recognize patterns. Neural networks have shown enormous potential in improving decision-making in various industries and in improving the prediction accuracy of machine learning algorithms. The above subset is designed to make the computer think. However, computer vision enables computers and systems to take action or make recommendations after obtaining meaningful information from digital images, videos, and other visual inputs, enabling computers to see, observe and understand (48). Notably, the robotic system is an AI system deployed in physical form to control physical objects in the world through supervised and unsupervised learning (49). Up to now, several types of robotics systems have been developed to assist humans in difficult or dangerous tasks ranging from healthcare to national defense. All of these lay the foundation for further application and development of AI.

The application of artificial intelligence in public health

Driven by major advances in computers algorithms and accumulation of big data over the decades, AI has entered an extraordinary stage of rapid development and widespread application. More recently, traditional AI research areas, including computer vision, speech recognition, and robotics, have also been found to be innovatively applicable in other real-world contexts, such as public health. In particular, the coronavirus pandemic outbreak at the end of 2019 plunged the world into a severe public health crisis. AI-based medical devices, algorithms, and other new industries have shown great potential in surveillance, prevention, diagnosis, and health management, which provides important support for this global fight against the epidemic.

Disease surveillance and prevention

Disease surveillance in public health surveillance aims to detect early and reliable signals of health anomalies and epidemic outbreaks from the diverse collection of data sources. Data sourcing and analysis are two major challenges for public health surveillance. AI-based ubiquitous social media, online newswires, and other internet-based data streams effectively leverage various open data beyond traditional public health surveillance systems through its powerful surveillance capabilities, which expand and facilitate data sourcing (50). Traditional data analysis is primarily achieved through statistical methods that focus primarily on macro-level conclusions. However, as data complexity increases and data volumes accumulate, statistical inference becomes quite difficult within the framework of these methods. AI-based analytics methods such as natural language processing and image processing converted unstructured data into structured items through semantic labeling and auto-population of features, which in turn enhances traditional statistics-based data analysis (50). In practice, multiple AI products, such as infrared thermal imaging and face recognition, contribute to monitoring and controlling the source of infection. These products expressly identify people with abnormal body temperature and close contact to determine the source of the disease in the case of dense crowds and a rapid flow of people.

Intelligent diagnosis

The most obvious manifestation of AI in public health is intelligent diagnosis. Intelligent diagnosis requires relevant personnel in medical institutions to collect and analyze a large amount of data and information by using modern information technology. Machine learning algorithms are then used to quickly identify the database of the cases to facilitate professionals making highly accurate diagnostic decisions (51). Recently, multiple auxiliary diagnostic AI devices have been approved by the U.S. Food and Drug Administration (FDA) for various diseases (52). IDx-DR is the first FDA-approved autonomous AI system that automatically analyzes retinal images for signs of diabetic retinopathy without the help of medical personnel (29). The clinical trial results showed that the accurate identification rates of IDx-DR for patients with more than mild diabetic retinopathy and those with less than mild diabetic retinopathy were 87.4 and 89.5%, respectively (53). Additionally, cancer diagnosis is one of the most important applications of AI-based intelligent diagnosis (54, 55). The algorithm developed based on deep learning was used to detect mammographic lesions with 99% accuracy, reducing unnecessary biopsies (56–59). Furthermore, colonoscopy videos can also be analyzed using AI to accurately identify polyps in real-time (60).

Excitingly, AI has shown potential in designing novel anticancer therapies or at least guiding the development of such therapies, which could reduce failure rates and shorten approval times (61, 62). The mechanism of anticancer molecules can be precisely predicted by AI algorithm BANDIT, leading to precise preclinical and clinical positioning, and increased likelihood of clinical success (63). Likewise, effective drug combinations can be predicted and screened based on AI tools, optimizing the treatment of cancer (64).

Health administration

Additionally, AI technology can also improve the efficiency and quality of health management in various ways such as AI-assisted decision-making systems, medical record quality control, and pathological assistance systems. Health protection and promotion inseparable from AI. With advances in AI, personalized predictions and prevention are possible (65, 66). Up to now, multiple disease prediction models had been developed and improved to provide targeted and personalized health advice (67–70). Furthermore, AI has also greatly contributed to the development of the psychological counseling industry. Chatbots like Wysa ensure empathic support and advise on when to consult a human practitioner (71). Deep neural network-based AliveCor can detect possible heart rhythm abnormalities in users by evaluating heart rate data, physical activity and other influencing factors, reminding people to proactively manage their heart health (72, 73).

Taken together, AI has shown a profound impact on disease surveillance, intelligent diagnosis, and health management in public health systems, indicating that AI will strongly promote public health toward a more intelligent and humanized direction.

The introduction of artificial intelligence in public health education

Public health education aims to equip students with sound theoretical understanding to meet complex health-related challenges with appropriate methods. Actually, almost all theoretical and practical issues related to health involve multidisciplinary collaboration (74, 75). However, only partial curriculums covered the necessity of interdisciplinarity in traditional public health education. In addition, theories, methods, health topics, and their applications are often taught side by side, making it difficult for students to combine them (74, 76). Fortunately, the application of AI in education brought new opportunities for health public education. The intelligence of public health education will provide guidance and technical support for training professionals in the new era, improving the efficiency and quality of education.

The application of artificial intelligence in public health education

Recently, AI has already been applied in education, especially with some tools that help develop skills and test systems. As AI-based educational solutions continue to mature, AI is expected to help fill gaps in learning and teaching needs, enabling schools, and teachers to do more (77). Computer systems combined by incorporating human intelligence could serve intelligent tutors, tools, or students, facilitating decision-making in educational settings. Understanding individual differences is essential for developing teaching tools for specific students and tailoring education to individual needs at different stages. Identifying individual differences is essential for developing pedagogical methods for specific students and customizing education for individual needs at different stages (78). A large amount of personal data can be accurately collected by intelligent education systems based on big data and AI technologies. Learning patterns of students is revealed through data analysis to identify their unique preferences and experiences (79). Therefore, AI and big data have the potential to realize personalized learning and achieve precision education. Additionally, several basic activities in education, such as grading, frequently asked questions, and predicting learning outcomes, were automated by AI, which liberate teachers and encourage them to focus on professional development (80, 81). AI solutions can identify weaknesses by assessing the learning history of students to provide courses suitable for improvement. Notably, AI breaks down the barriers between schools and traditional grades and promotes the balance of teaching resources. Widespread application of virtual learning promotes the balance of teaching resources. Intelligent tutoring systems are an integral part of AI in education (82). These systems, such as AI chatbots, AI tutors, and tutoring programs, provide one-on-one instruction and feedback (83–85).

The application of AI technology in public health education focuses on the teaching of theoretical courses, which is in the innovation stage of educational informatization process. The traditional teaching pattern has been improved on the basis of computers and the Internet to achieve a certain degree of autonomous learning, collaborative learning, and teaching feedback. Notably, how to apply theoretical knowledge into practice is the focus of public health education beyond theoretical study. However, compared with other subjects that have gone beyond the theoretical stage, such as situational, inquiry-based and simulated medicine, there is a gap in the application of AI in public health education practice.

Recommendations of the standardized curriculum

Objectives of the AI-based public health core course include recognizing major research and discoveries of AI in public health, and understanding learning potential applications in public health practice. The core curriculum should begin with basic mathematics and statistics lessons related to AI (86). Then, high-quality courses covering AI, machine learning, deep learning, and data science serve as the core curriculum of public health education, allowing students to focus on applications of

these subjects more naturally in subsequent training. Finally, the curriculum should focus on how AI can be used in public health practice, such as disease prevention, infection source control, and health management (29). Specialized courses with extracurricular activities and dedicated training should also be considered for those students who wish to learn more. Additionally, refresher courses should also be provided for licensed professionals.

Conclusions and prospects

With the increasing emphasis on public health education, the reform of teaching methods and the change of personnel training mode need to be accelerated. A new-era education system with interactive learning and intelligent learning as the main content urgently needs to be established. However, the existing facilities in medical colleges are difficult to achieve personalized education for students. The low education collaboration and the conflict between intelligent teaching and traditional teaching are not conducive to meeting the demand of society for higher-quality educational resources in public health education. The introduction of AI into education will open up novel opportunities to dramatically improve the quality of teaching and learning. On the one hand, AI enhances the personalization of student learning plans and lessons and facilitates tutoring by helping students improve their weaknesses and improve skills. On the other hand, educators could benefit from intelligent systems that facilitate assessment, data collection, and improved learning progress. Recently, AI has been introduced into various fields in education, such as ophthalmology (29), radiology (30), music (87), and physical (31), providing mature technical support and effectively promoting its development in a more intelligent and humanized direction. Therefore, with the help of education section, we could reform public health education and design formal integrated AI curriculum in medical schools to better equip public health professionals to respond to emergencies. It is believed that soon, public health education based on AI will inject unprecedented impetus into the development of the public health and improve the ability of public health system to respond to emergencies.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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.

Publisher's note

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EDITED BY
Christiane Stock,
Charité Medical University of Berlin, Germany

REVIEWED BY
Chu Lin,
Peking University People's Hospital, China
Heng Su,
The First People's Hospital of Yunnan Province, China

*CORRESPONDENCE
Xiajie Shi
✉ bob-xiajie@csu.edu.cn
Zhen Wang
✉ wangzhencs@csu.edu.cn

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Primary care providers' knowledge, attitudes, and practices related to prediabetes in China: A cross-sectional study

Linhua Pi[1,2,3], Jianru Yan[4], Dongxue Fei[1,5], Ying Zheng[1,6], Xiajie Shi[1,2,3]*, Zhen Wang[1,2,3]* and Zhiguang Zhou[1,2,3]

[1]Department of Metabolism and Endocrinology, The Second Xiangya Hospital, Central South University, Changsha, China, [2]Key Laboratory of Diabetes Immunology (Central South University), Ministry of Education, Changsha, China, [3]National Clinical Research Center for Metabolic Diseases, Changsha, China, [4]Department of Metabolic Endocrinology, The First People's Hospital of Pingjiang, Yueyang, China, [5]Clinical Nursing Teaching and Research Section, The Second Xiangya Hospital of Central South University, Changsha, China, [6]Center for Medical Research, The Second Xiangya Hospital, Central South University, Changsha, China

Background: The management of prediabetes has great clinical significance, and primary care providers (PCPs) play important roles in the management and prevention of diabetes in China. Nevertheless, little is known about PCPs' knowledge, attitudes, and practices (KAP) regarding prediabetes. This cross-sectional study aimed to assess the KAP regarding prediabetes among PCPs in the Central China region.

Methods: This cross-sectional study was conducted using self-administered KAP questionnaires among PCPs from Central China region.

Results: In total, 720 PCPs completed the survey. Most physicians (85.8%) claimed to be aware of the adverse effects of prediabetes and reported positive attitudes toward prediabetes prevention, but the PCPs' knowledge of prediabetes and management practices showed substantial gaps. The prediabetes knowledge level and practice subscale scores of the PCPs were only 54.7% and 32.6%, respectively, of the corresponding optimal scores. Female PCPs showed higher prediabetes knowledge level scores ($p = 0.04$) and better practice scores ($p = 0.038$). Knowledge and attitude scores were inversely correlated with participants' age and duration of practice ($p < 0.001$). The PCPs who served in township hospitals had significantly higher knowledge and attitude scores than those who served in village clinics ($p < 0.001$). Furthermore, knowledge and practice scores increased with increasing professional titles. Recent continuing medical education (CME) attendance had a significant positive influence on knowledge of prediabetes ($p = 0.029$), but more than four-fifths of the surveyed PCPs did not participate in diabetes-related CME in the past year.

Conclusions: Substantial gaps were observed in PCPs' knowledge and practices regarding prediabetes in the Central China region. CME programmes were under-utilized by PCPs. Structured programmes are required to improve PCPs' prediabetes-related knowledge and practices in China.

KEYWORDS

prediabetes, KAP, primary care providers, China, cross-sectional study

Introduction

Prediabetes is a borderline glycaemic status presenting with impaired glucose metabolism that does not meet the diagnostic criteria for diabetes. According to the recent guidelines from the American Diabetes Association (ADA), prediabetes is defined by fasting plasma glucose (PG) level of 5.6–6.9 mmol/l, a 2-h PG level of 7.8–11.0 mmol/l in a 75-g oral glucose tolerance test (OGTT), and a hemoglobin A1c level of 5.7%−6.4% (1). A recent national survey indicated that the prevalence of prediabetes was 35.2% among adults living in China; thus, approximately 357 million Chinese have prediabetes (2). Furthermore, prediabetes is associated with a high risk of progression to overt type 2 diabetes (3) and may confer an increased risk of premature mortality (4, 5) and multiple chronic complications observed in established diabetes (6, 7). Numerous studies have confirmed that lifestyle interventions and medications are effective in delaying or preventing the development of diabetes (8–10).

Despite the success of preventive interventions, nearly 90% of individuals with prediabetes are not informed of their conditions by health providers (11) and most American patients with prediabetes do not receive appropriate interventions (12, 13). The situation in China may be worse, especially in the rural regions. Primary care physicians (PCPs) from townships or village doctors play a vital role in diabetes prevention by screening for and managing prediabetes. Thus, PCPs' knowledge of prediabetes and their attitudes and practices related to this condition are essential elements of prediabetes management. Previous studies conducted in the US (14, 15) and Latin America (16) indicated significant gaps in the knowledge of prediabetes among PCPs as well as inadequate detection and treatment of this condition by PCPs. Thus, understanding PCPs' knowledge, attitudes, and practices (KAP) related to prediabetes can facilitate the development of tailored strategies to improve knowledge, change attitudes, and address poor practices. To the best of our knowledge, PCPs' KAP related to prediabetes in China has not been described to date. Therefore, this study aimed to assess PCPs' knowledge of prediabetes as well as their attitudes toward prediabetes and prediabetes care practices in the Central China region. We also aimed to evaluate the association between provider characteristics and prediabetes-related KAP.

Methods

This cross-sectional study was conducted between May and August 2022. Letters of invitation were sent to PCPs from township hospitals or village doctors across Yueyang, Huaihua, and Yongzhou cities in Hunan Province, Central South China. Those who agreed to participate were provided with a questionnaire through an online platform in China, which provided functions equivalent to Amazon Mechanical Turk. This study was approved by the Ethics Committee of the Second Xiangya Hospital of Central South University, and written consent was obtained from each participant.

The self-administered questionnaire included multiple-choice and open-ended questions evaluating participants' prediabetes KAP and was developed in line with the concepts proposed by a Johns Hopkins University group (15). A pre-test was conducted among 10 PCPs to test the reliability and improve the clarity and interpretability of the questionnaire. The questionnaire consisted of two sections. The first section focused on PCPs' sociodemographic characteristics (sex and age), practice setting (township hospital or village clinic), physician seniority level, time since graduation in general medicine, history of diabetes in a first-degree relative, and experience of continuing medical education (CME) programmes related to diabetes in the past year. The second section was developed according to the latest ADA criteria and the Chinese Diabetes Society guidelines released in 2020 (17). It consisted of 16 questions on the participants' prediabetes-related knowledge (6 questions), attitudes (6 questions), and practices (4 questions). Questions related to knowledge and practice were evaluated using a two-point scale (1 = correct, 0 = false, and not sure). The questions related to attitude used a five-point Likert scale (1 = positive attitude, 0 = negative practice, or uncertain). Additionally, we asked providers to select what they considered significant challenges to lifestyle modification from a list of potential barriers drawn from prior studies regarding similar topics (14, 16) and asked them to list other possible potential barriers they encountered in daily clinical practice.

Statistical analyses

Data were extracted from the questionnaires and analyzed using SPSS version 25.0 (IBM Corporation, Chicago, IL, USA). Descriptive data were presented as numbers, percentages, means, and standard deviations, depending on whether the variables were categorical or continuous. The association between PCPs' characteristics and respondents' KAP was evaluated by Chi-square tests and *t*-tests, as appropriate. Multiple linear regression models were used to examine the association between the predictor variables and the KAP scores. Statistical significance was set at $P < 0.05$.

Results

Sociodemographic and other characteristics of the participants

This study enrolled 720 PCPs from the three cities in Hunan Province, Central China. The characteristics of the study participants are summarized in Table 1. The mean age of the participants was 44.7 ± 9.8 years. Among the participants, 65.5% were male, and 260 and 460 physicians worked in township hospitals and village clinics, respectively. The physicians involved in this study included 630 resident, 79 attending, and 11 senior physicians. Among them, 117 had practiced for <10 years, 124 for 10–20 years, and 479 for >20 years. The majority (73.1%) of respondents had not participated in CME programmes related to

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TABLE 1 Characteristics of the study participants ($N = 720$).

Provider characteristics	Mean ± SD	Number (*n*)	Percentage (%)
Sex			
Male		472	65.5%
Female		248	34.5%
Age (years)	44.7 ± 9.8		
≤40		218	30.3%
>40		502	69.7%
Practice setting			
Township hospital		260	36.1%
Village clinic		460	63.9%
Professional titles			
Resident physicians		630	87.5%
Attending physicians		79	11.0%
Senior physicians		11	1.5%
Duration of practice (years)	22.7 ± 11.7		
<10 years		117	16.3%
10–20 years		124	17.2%
≥20 years		479	66.5%
CME attendance during the past year			
No		526	73.1%
Yes		194	26.9%
Positive family history of diabetes			
Yes		113	15.7%
No		607	84.3%

SD, standard deviation; CME, continuing medical education.

diabetes in the past year, and 113 respondents had a family history of diabetes.

Physicians' knowledge regarding prediabetes

The participants were asked if they knew what prediabetes was and to identify the risk factors for diabetes. While 86.5% had adequate knowledge of the definition of prediabetes, 71.9% had sufficient knowledge of the risk factors for diabetes. However, the PCPs generally lacked knowledge of glycaemic cut-offs for the diagnosis of prediabetes, and only 50.4%, 56.4%, and 26.1% could identify the correct glycaemic cut-offs for diagnosing prediabetes based on the fasting glucose level, 2-h PG level during OGTT, and hemoglobin A1c level, respectively. Overall, only 62 of the 720 PCPs (8.6%) correctly identified all three glycaemic cut-off values for the diagnosis of prediabetes, while 116 PCPs (16.1%) were unaware of all three cut-off values. Less than half of the PCPs (37.5%) chose 5%—7% as the recommended minimum amount of weight loss (Table 2).

TABLE 2 Knowledge of PCPs regarding prediabetes.

Item	Correct choice *n* (%)	Score [0–1] Mean ± SD
Is prediabetes an intermediate stage between normal glycemia and diabetes?	623 (86.5%)	0.87 ± 0.34
Which one is not a risk factor in prediabetes screening?	518 (71.9%)	0.72 ± 0.45
Which one is the prediabetes laboratory criteria for fasting glucose level?	363 (50.4%)	0.50 ± 0.50
Which one is the prediabetes laboratory criteria for the 2-h PG level during OGTT?	406 (56.4%)	0.56 ± 0.50
Which one is the prediabetes laboratory criteria for HbA1c level	188 (26.1%)	0.26 ± 0.44
Which one is the correct body weight loss recommendation for individuals with prediabetes?	270 (37.5%)	0.37 ± 0.48
Total	2,361 (54.7%)	3.29 ± 1.19

2-h PG, 2-h plasma glucose; OGTT, oral glucose tolerance test; HbA1c, hemoglobin A1c.

TABLE 3 Attitudes of PCPs regarding prediabetes.

Item	Positive attitude *n* (%)	Score [0–1] Mean ± SD
Prediabetes is associated with a high risk of progression to overt type 2 diabetes	662 (91.9%)	0.92 ± 0.27
Prediabetes is associated with an increased risk of premature mortality	654 (90.8%)	0.91 ± 0.28
Most individuals with prediabetes have not been diagnosed	603 (83.8%)	0.84 ± 0.37
Prediabetes is reversible	568 (78.9%)	0.79 ± 0.41
Regular exercise helps delay or prevent the transition from prediabetes to diabetes	685 (95.1%)	0.95 ± 0.22
Metformin helps delay or prevent the transition from prediabetes to diabetes	533 (74.0%)	0.74 ± 0.44
Total	3,705 (85.8%)	5.15 ± 1.12

Physicians' attitudes toward prediabetes

Regarding attitudes toward prediabetes, more than 90% of the respondents deemed that prediabetes increased the risk of diabetes development and premature mortality, and more than 80% reported that most participants with prediabetes were unaware of their condition. Meanwhile, the majority of participants showed a positive attitude toward prediabetes prevention; 78.9% thought prediabetes was reversible through regular exercise and drugs (metformin) (Table 3).

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TABLE 4 PCPs' prediabetes-related practices.

Item	Correct choice *n* (%)	Score [0–1] Mean ± SD
Which one is your initial suggestion for individuals with prediabetes?	653 (90.1%)	0.91 ± 0.29
How long do you recommend individuals with prediabetes to repeat laboratory work?	50 (6.9%)	0.07 ± 0.25
How long do you recommend individuals with prediabetes to return for follow-up clinic visit?	177 (24.6%)	0.25 ± 0.43
Management of a patient who failure to respond to lifestyle modification	59 (8.2%)	0.08 ± 0.27
Total	939 (32.6%)	1.30 ± 0.66

Physicians' prediabetes-related practices

The overall practice score was low. Diet changes and physical activity were the most frequently employed methods for prediabetes management (90.1%), followed by repeat laboratory work and follow-up clinic visits for individuals with prediabetes. Fifty (6.9%) and 177 (24.6%) of the surveyed PCPs identified the right choices recommended by the ADA guidelines and Chinese expert consensus, respectively. Only 59 (8.2%) PCPs prescribed drugs (metformin, acarbose, etc.) to patients who failed to respond to lifestyle modification (Table 4).

Barriers to lifestyle modification

At the time of the survey, most PCPs selected lack of recognition of the harm posed by prediabetes (94.0%), lack of diet and exercise guidance (91.4%), uncertainty of the effectiveness of lifestyle modifications (88.5%), and lack of motivation (82.2%) as barriers to lifestyle modification. Additionally, 237 (23.9%) PCPs listed a lack of resources or financial limitations as a potential barrier in the open-ended question.

Correlations among KAP scores

The total mean scores for knowledge, attitude, and practice were 3.29, 5.15, and 1.30, respectively, out of possible scores of 6, 6, and 4, respectively. The knowledge and attitude scores showed a weak positive correlation ($p = 0.001$, $r = 0.127$), similar to the knowledge and practice scores ($p = 0.004$, $r = 0.1107$).

Factors associated with the overall KAP scores

The associations between the KAP scores and provider characteristics are presented in Table 5. Female PCPs reported significantly more prediabetes-related knowledge and practices than males. They also reported high mean attitude scores; however, the differences were not statistically significant. The knowledge and attitude scores varied significantly according to age; the lower age group showed higher scores, but with the practice score, the trend was reversed even though the difference was not statistically significant. Working in township hospitals was a significant predictor of higher knowledge and attitude scores.

Professional titles also showed statistically significant relationships with knowledge scores. The scores increased with increasing professional titles. The duration of practice was significantly associated with the knowledge and attitudes toward prediabetes. Respondents in the group with <10 years of experience showed the highest knowledge score, whereas respondents in the group with 10–20 years of experience showed the highest attitude score. CME attendance during the past year had a significant positive influence on knowledge of prediabetes.

The joint effect of provider characteristics on KAP scores was evaluated using multiple regression analysis. Professional title was a significant provider characteristic that predicted the knowledge level of participants. Significant provider characteristics that predicted the attitude of participants were sex and the practice setting. However, none of the factors included in our study could predict the practice scores of the participants.

Discussion

To improve the management of diabetes and other chronic diseases, the Chinese government implemented the National Basic Public Health Services (BPHS) programme in 2009 (18). PCPs play a crucial role in this programme. The BPHS programme offers blood glucose tests, blood pressure measurements, lifestyle consultations, and medical instructions for people with diabetes. To provide a practical tool for doctors, especially for PCPs and general practitioners, The Chinese Diabetes Society released an expert consensus regarding prediabetes in 2020 (17). However, little is known about the competence of PCPs to perform this role. We conducted the first KAP study on prediabetes among Chinese PCPs from the Central China region. In the present study, most physicians (85.8%) claimed to be aware of the harmful effects of prediabetes and reported positive attitudes toward prediabetes prevention, but a substantial gap was noted in PCPs' knowledge of prediabetes and management practices. The PCPs' knowledge level for prediabetes was 54.7% of the optimal level, while their practice subscale score was 32.6% of the optimum score. Our findings showed that female PCPs had higher levels of prediabetes knowledge and better practices. The knowledge and attitude scores were inversely correlated with the participants' age and duration of practice. PCPs who served in township hospitals had significantly higher knowledge and attitude scores than those who served in village clinics. Furthermore, knowledge and practice scores increased with increasing professional titles. We also found that CME attendance in the past year had a significant positively influence on knowledge of prediabetes.

Our study revealed a suboptimal level of prediabetes knowledge regarding diagnostic criteria among PCPs, which may lead to low rates of identification of patients with prediabetes. Only 62

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TABLE 5 Overall knowledge, attitude, and practice mean scores and provider characteristics.

Provider characteristics		Knowledge score		Attitude score		Practice score	
	n	Mean (SD)	*p*	Mean (SD)	*p*	Mean (SD)	*p*
Sex							
Male	472	3.20 ± 1.16	0.04	5.10 ± 1.15	0.477	1.27 ± 0.65	0.038
Female	248	3.47 ± 1.16		5.16 ± 1.10		1.38 ± 0.69	
Age (years)							
≤40	218	3.57 ± 1.16	<0.001	5.40 ± 1.10	<0.001	0.65 ± 0.44	0.288
>40	502	3.17 ± 1.18		5.03 ± 1.11		0.67 ± 0.30	
Practice setting							
Township hospital	260	3.55 ± 1.23	<0.001	5.45 ± 1.03	<0.001	1.35 ± 0.67	0.202
Village clinic	460	3.14 ± 1.14		5.0 ± 1.13		1.28 ± 0.66	
Professional titles							
Resident physicians	630	3.23 ± 1.16	0.001	5.12 ± 3.21	0.473	1.31 ± 0.68	0.041
Attending physicians	79	3.72 ± 1.31		5.26 ± 0.97		1.20 ± 0.49	
Senior physicians	11	3.82 ± 1.08		5.36 ± 0.67		1.73 ± 0.90	
Duration of practice (years)							
<10 years	117	3.63 ± 1.12	<0.001	5.33 ± 1.14	<0.001	1.36 ± 0.65	0.265
10–20 years	124	3.43 ± 1.20		5.42 ± 0.92		1.36 ± 0.65	
≥20 years	479	3.17 ± 1.18		5.02 ± 1.15		1.28 ± 0.67	
CME attendance							
No	526	3.23 ± 1.19	0.029	5.22 ± 1.09	0.274	1.29 ± 0.65	0.448
Yes	194	3.45 ± 1.17		5.12 ± 1.13		1.34 ± 0.71	
Positive family history of diabetes							
Yes	113	3.48 ± 1.20	0.066	5.16 ± 1.13	0.339	1.40 ± 0.66	0.101
No	607	3.25 ± 1.18		5.05 ± 1.06		1.29 ± 0.66	

CME, continuing medical education.

of the 720 PCPs (8.6%) correctly identified all three glycaemic cut-off values for the diagnosis of prediabetes, and 16.1% were not aware of any of the glycaemic cut-off values for prediabetes diagnosis. Our findings were comparable with those obtained by other researchers in America (14, 15) and Latin America (16) who also reported large gaps in prediabetes knowledge among PCPs. While ∼90% of individuals with prediabetes in the US are not informed of their conditions by healthcare providers (11), the situation in China is expected to be much worse. The low awareness of prediabetes could be partly attributed to the lack of optimal knowledge of prediabetes among PCPs. We also found that PCPs lacked knowledge of evidence-based recommendations for prediabetes. Weight loss is the most important factor in reducing the risk of incident diabetes, and evidence suggests that 5%−7% weight loss is sufficient to achieve this goal (19–21). Knowledge of this weight-loss target is essential for providing lifestyle consultations for patients with prediabetes. Previous studies have demonstrated that most patients with prediabetes do not receive appropriate interventions (12, 13). In our study, only 37.5% of respondents correctly identified the guideline recommendations for weight loss; addressing this knowledge gap may improve the management of prediabetes. We also observed that PCPs with a younger age and a shorter duration of practice possessed a higher level of knowledge than their counterparts. A previous study also showed that the diabetes knowledge of Iranian internists was inversely correlated with the participants' age and duration of practice (22). This could be attributed to the fact that younger PCPs are more likely to keep abreast with the current trends in prediabetes. An important finding of our study was that participation in CME regarding diabetes could significantly improve PCPs' prediabetes knowledge, which is in accordance with previous studies regarding diabetes knowledge among PCPs (23–25). However, more than four-fifths of the surveyed PCPs had not participated in CME regarding diabetes in the past year. Although many CME programs are available for PCPs, they are under-utilized. One possible reason might be the COVID pandemic preventing the in-person participation. As a newly emerging technology, telemedicine has demonstrated enormous potential to provide an effective intervention in health care (26, 27). To this end, telemedicine may be a feasible

approach for overcome part of barriers during the COVID-19 pandemic period.

The current study indicated that most of the respondents deemed that prediabetes increased the risk of development of diabetes and premature mortality, and more than 80% believed that most patients with prediabetes were unaware of their condition. Meanwhile, the majority had a positive attitude toward prediabetes prevention: 78.9% thought prediabetes was reversible through regular exercise and drugs (metformin). Similar to the findings for the knowledge subscale, the overall attitude scores were inversely correlated with the participants' age and duration of practice, which could also be due to the fact that younger PCPs are more likely to keep abreast with current trends in prediabetes. Moreover, PCPs who served in township hospitals had significantly higher attitude scores than those who served in village clinics, which could be because PCPs, who served in township hospitals had greater accessibility to the latest medical knowledge.

We found some poor practices related to prediabetes among PCPs. In our survey, only 24.6% and 6.9% of the PCPs reported familiarity with the Chinese expert consensus, which recommends the interval for clinical follow-up and repeat laboratory assessments (17). Thus, very few PCPs were aware of the expert consensus, and addressing this problem may improve delivery of care for prediabetes. In a Diabetes Prevention Program study, lifestyle modification or metformin treatment was proven to be effective in reducing the incidence of diabetes and the risk of microvascular complications (9, 28). However, consistent with the results of previous studies (14–16), very few PCPs considered metformin use for prediabetes. This may be due to skepticism regarding the effectiveness of metformin (29).

The PCPs identified a lack of diet and exercise guidance as well as resource or financial limitations as important system-level barriers, and patient-related factors such as lack of recognition of prediabetes, uncertainty regarding the effectiveness of lifestyle modification, and lack of motivation as barriers to lifestyle modification. Therefore, goal-oriented measurements to tackle these barriers will be key to cost-effective management of prediabetes.

Limitations

The present study had several limitations. First, this study was conducted among PCPs from the Central China region; due to variations in geographical and sociocultural characteristics across China, the results may not be generalizable. Second, the results of the KAP survey were self-reported by the participants, which may have introduced recall and social desirability biases, with more respondents reporting positive attitudes toward prediabetes.

Conclusion

This study highlighted the substantial gaps in knowledge and practices regarding prediabetes among PCPs in the Central China region. The results also indicated underutilisation of prediabetes CME programmes by PCPs. Since PCPs play a crucial role in the prevention and management of diabetes, efforts to address these gaps in prediabetes knowledge and practice are of urgent importance. Structured programmes should be planned to improve prediabetes-related knowledge and practices among PCPs in China. In view of this, we make the following suggestions:

1. Educating providers on expert consensus regarding prediabetes, online education may be a candidate approach.
2. Develop a simplified prediabetes management algorithm by Chinese Diabetes Society.

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 human participants were reviewed and approved by the Ethics Committee of the Second Xiangya Hospital of Central South. The patients/participants provided their written informed consent to participate in this study.

Author contributions

XS and ZW designed the study. LP, DF, and YZ collected the data. LP conducted the data analysis and drafted the manuscript. XS, ZW, and ZZ revised the manuscript. JY carefully edited the revised manuscript. All authors read and approved the submitted version of the 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

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EDITED BY
Yihui Du,
University Medical Center
Groningen, Netherlands

REVIEWED BY
Maram Gamal Katoue,
Kuwait University, Kuwait

*CORRESPONDENCE
Hong Qian
✉ qianhong2222@126.com
Xiuhe Zou
✉ zouxiuhe1986@163.com

†These authors have contributed equally to this work

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Game-based learning in medical education

Maosen Xu[1†], Yong Luo[2†], Yu Zhang[1], Ruolan Xia[1], Hong Qian[3*] and Xiuhe Zou[4*]

[1]Division of Biotherapy, Cancer Center, West China Hospital, Sichuan University, Chengdu, China, [2]Department of Head and Neck Oncology, West China Hospital, Sichuan University, Chengdu, China, [3]Department of Cardiovascular Surgery, West China Hospital, Sichuan University, Chengdu, China, [4]Department of Thyroid Surgery, West China Hospital, Sichuan University, Chengdu, China

At present, medical education is rapidly evolving. Game-based learning (GBL) has been gradually used for education, and several innovations have emerged. The emergence of serious games and gamification provides alternative approaches for educators to improve the medical teaching process. Both serious games and gamification exert their education-promoting function by providing the possibility of combining learning activities such as feedback, testing, and spaced repetition with active participation and autonomy as well as positive experiences for students. Developing effective GBL modalities has the potential to bring immersive experiences for medical students and improve their study outcomes. Herein, we reviewed recent studies employing GBL in medical education, including serious games and gamification teaching. Furthermore, we also discussed the effectiveness and limitations of GBL to suggest future directions for the development and application of GBL in medical education.

KEYWORDS

game-based learning, serious game, gamification, medical education, teaching activity

1. Introduction

With the rapid development of modern technologies and the iterations of educational concepts, the repertoire of untraditional strategies for education is becoming wider gradually. Among these novel and appealing methods, game-based learning (GBL) is fast developing as an interesting and innovative teaching approach in the field of education currently (1). Over the recent years, mounting evidence suggests that GBL can improve engagement and stimulate the motivation of students to learn, as well as promote teaching outcomes (2–8).

At present, GBL is a new trend and is extensively applied in a wide spectrum of disciplines. Given the actuality that medical students are more receptive to new things and keen on modern technologies, various interesting games are also more frequently used in medical teaching (9, 10). As opposed to more traditional instructional approaches, the main modality of GBL is adding diverse game elements to other non-game areas to encourage engagement and raise the enthusiasm of participants. The scope of GBL is extensive, and it covers both non-technological and technological integration of games within the teaching activity (1). GBL is typically referred to as "serious games," "educational games," and "gamification" in both undergraduate courses and clinical studies. The formal definition of serious games is an interactive computer application that has a challenging goal and incorporates

some scoring mechanism, therefore providing users with practical knowledge, skills, or attitudes in real life (11, 12). Gamification is another strategy of GBL, and it can be described as a process of game-thinking and game mechanics to engage users and solve problems (13, 14). Both these methods are currently used to promote medical education.

Simulation-based education (SBE) is another teaching strategy that can provide a relatively safe practice environment for both learners and patients in the field of medical education. SBE has the potential to help learners acquire technical skills and non-technical skills including leadership, teamwork ability, and communication (15–17). Despite having similar purposes and application prospects, the differences between SBE and GBL remain. The main model of GBL is adding game elements to other non-game areas to encourage engagement, which emphasizes the application of game elements in teaching activity and finally improves teaching results (1). However, medical simulation is broadly categorized into four areas, namely, a partial-task simulator, a screen-based computer, standardized patients, and high-fidelity mannequin simulators. By using these teaching tools, SBE largely allows learners to practice their clinical skills without patients being put at risk (15).

It is now becoming increasingly recognized that the application of game elements in education will provide an engaging and enjoyable way of learning and contribute to valuable improvements in studying outcomes. Furthermore, the appearance and epidemic of COVID-19 exerts a profound influence on medical education and enables educators to search for viable pedagogical models continuously (18). To avoid a large-scale epidemic of COVID-19 and provide appropriate social distancing, numerous educative institutions had to undergo shutdown to varying degrees. In this condition, GBL can help students to enrich their study experience and enhance their collaboration during social distancing. Therefore, the application of gamified elements in education has enormous potential to create an educational and engaging studying journey for students and can be seen as a promising option to enrich current teaching methods.

In this review, we overview recent studies employing GBL in medical education, including serious games and gamification teaching. Furthermore, we also discuss the effectiveness and limitations of GBL, to suggest future directions for the development and application of GBL in medical education.

2. Methods

We performed a PubMed search using the following search terms: "game-based learning AND medical education," "serious game AND medical," "educational games AND medical," and "gamification AND medical." We reviewed and assessed all abstracts of those searched literature carefully to select appropriate articles including original articles, meta-analyses, and reviews. Meanwhile, we excluded articles that do not belong to the field of medical education. As a result, we made summaries according to different categories in the next sections.

3. Serious games in medical education

Apart from entertainment function, another purpose of serious games is to be a pedagogical tool, which provides a way of interactive learning for medical education and constitutes a balanced combination between learning activity and amusement (11). Serious games include playing elements to support educational objectives deliberately and are generally illustrated as digital games that inform, educate, and train (19). It can also be done in different formats such as digital, card, and board games (20). The benefits of serious games on learners include enhancing their collaborative awareness *via* multiplayer settings, providing them with opportunities for active learning to better solve clinical problems, and improving their clinical reasoning, decision-making skills, clinical performance, and the like (5, 21, 22). As such, serious games have potential alternatives for supplementing traditional simulation-based education and contributing to better academic performances of medical students (23). Various serious games in medical teaching activity together with their main proposes and advantages are listed in Table 1.

The primary objectives of research regarding serious games in medical education are assessing their playability, practicability, and pedagogical outcomes for some specific contexts and diseases, and widespread efforts have been put into this. In the field of surgical medical teaching, some enjoyable games have been designed and obtained good results. For example, the game "Cleft Island" was developed to test whether learners could benefit from and gain related medical knowledge from this studying format as well as measure the game experience of students (24). The game development is made up of three components including "mechanic," "dynamic," and "aesthetic," which aims to give participants a better experience. The results demonstrate that this game can be used as an effective supplementary instructional material and improve students' knowledge of treatment protocol (24). Another game, named "EMERGE," was applied to explore the implication of GBL on students' declarative and procedural knowledge, which was achieved by the design of a pretest-posttest manner (25). Specifically, students were asked to complete questions concerning declarative and procedural knowledge before and after playing the "EMERGE," respectively. The result demonstrated that this pretest-posttest comparison increased students' knowledge and yielded a positive impression of them. However, this research failed to test the long-term effects of this game (25).

Serious games are also used in the course of pediatric teaching. Recently, Gerard et al. designed a first-person serious game termed "PediatricSim" that was intended to teach and evaluate students' performances in different pediatric settings such as respiratory failure, diabetic ketoacidosis, and septic shock (26). By selecting from distant treatment options, all participants were put in the role of a code leader and direct patient management to improve their cognizance of pediatric emergencies. Furthermore, this survey also assesses the engagement of students and the educational value of "PediatricSim." It is gratified that most subjects rated the game favorably for engagement, educational value, and realism (26). Another game "NEOGAMES" aimed at promoting pediatric education to improve long-term knowledge retention of students

TABLE 1 Serious games in medical teaching activity.

Game name	Filed	Game type	Country and year	Game propose	Advantages	Reference
Cleft Island	Surgery	Online game	Thailand, 2019	To develop and evaluate the effectiveness of serious game to deliver knowledge	Improving students knowledge	(24)
EMERGE	Surgery	Online game	Germany, 2019	To test the effect of the game on students' declarative and procedural knowledge, as well as their satisfaction.	Increasing students declarative knowledge	(25)
PediatricSim	Pediatry	Online game	America, 2018	To teach and assess students performances on several critical pediatric scenarios	Improving students engagement and test result	(26)
NEOGAMES	Pediatry	Online game	China, 2020	To train students in neonatal resuscitation and to examine whether the game improves their long-term knowledge retention	Facilitating learning and promoting short-term and long-term knowledge retention	(27)
AntibioGame®	Lemology	Online game	France, 2019	To evaluate the usability and playability of the game	Improving students knowledge in antibiotic prescription	(28)
Hygie	Continuing medical education	Prototype video game	France, 2019	To evaluate the effectiveness and satisfaction of the game	Promoting CME in an effective, pleasant, and evidence-based way.	(29)
"spaced-education" game	Continuing medical education	Electronic questionnaire	America, 2012	To assess the efficacy of the game as a method of CME among physicians.	Substantially improving guidlines knowledge and is a well-accepted method by students	(30)
InsuOnline©	Continuing medical education	Questionnaire	Brasil, 2015	To improve the knowledge of undergraduate students and medicine residents about insulin therapy	A good option for large-scale continuing medical education on diabetes.	(31)
Fydlyty	Quality-oriented education	Online game	Canada, 2017	To improve medical-based cultural competence education	Providing an engaging, easily accessible and modifiable, and cost-effective cultural competence training tool	(32)
Happy families	Physiotherapy education	Card game	Belgium, 2022	To assist learners to develop their clinical reasoning proficiency and help learners develop adaptive expertise	Improving students clinical reasoning capacity	(33)
GridlockED	Emergency	Board game	Canada, 2019	To identify teaching points to which learners are exposed while playing the game.	Creating opportunities for engaging medical learners in systems-level teaching	(34)
COVIDgame	Epidemiology	Offline Game	China, 2021	To explore the effectiveness of the game for improving medical students' COVID-19 knowledge	Improving students knowledge retention	(35)
eMedOffice	Medical practice	Computer-aided game	Germany, 2011	To teach medical students the organizational and conceptual basics of the medical practice of a general practitioner	Promoting the future development of more effective serious games	(36)
APS Game	Health care education	Online game	Brazil, 2019	To compare the influence of the game dedicated to primary health care with traditional learning methods on students knowledge	Improving the students' knowledge effectively	(37)

and successfully train students in neonatal resuscitation in a cost-friendly and accessible manner (27).

Limited curricular time typically hinders teaching effects of infectious diseases. As a complementary device, serious games contribute to efficaciously pedagogical outcomes by creating highly immersive experiences for users. A serious game, AntibioGame®, integrates various game techniques and elements including cartoon graphics, mascots, and avatars, which aim to improve the training of medical students in the antibiotic application and test its usability and playability. As a result, 96% of students liked it and all students said they would recommend it to others (28).

In addition to imparting expertise, serious games also play crucial roles in medical-based cultural competence education. By providing an engaging, easily accessible, and modifiable training

tool, the game "Fydlyty" is shown to be intuitive and promote medical-based cultural competence education. It incorporates a scenario editor and dialogue authoring tool as well as employs low-fidelity visuals, which enables educators and students to access it directly in a more intuitive and simple way (32). Furthermore, serious games can also be used to teach medical residents for improving their management and leadership skills, since many of them think that leadership and negotiation are two additional domains they need (38).

There are multiple serious game modalities in the type of experiences created for medical students. Different from online games that consisted of complicated elements, both card games and board games have the potential to generate ideal teaching outcomes in a low-cost and more available manner. Hage et al. designed a comprehensive and structured card game "Happy Families" that enhanced learning enjoyment and promoted the cognition of students by making learners analyze subjective and physical examinations of a given patient (33). GridlockED is a multiplayer cooperative board game designed to assist learners in understanding the concepts of prioritization and patient flow in the emergency department. The investigators also tried to identify teaching points when students are playing the GridlockED game (34). These innovative teaching formats are emerging as complementary devices and represent promising options for classes. As for their long-term efficiency and applicability in veritably clinical practices, further investigations are needed.

The epidemic of COVID-19 has reshaped public awareness and posed great challenges for the field of medical education. One of the implications on education is that COVID-19 leads to large-scale disruption of university teaching activity (39). In this context, it is necessary to develop innovative approaches for medical teaching about basic knowledge of COVID-19 because most medical students will face and treat patients with COVID-19. To enrich teaching activities and help students to acquire COVID-19 knowledge effectively, Hu et al. designed a novel game named "COVIDgame" and compared its effectiveness in improving medical students' COVID-19 knowledge with online lectures (35). The game is composed of three separate parts including choosing the right order for putting on and taking off personal protective equipment, recognizing patients with COVID-19 promptly, and assessing confirmed patients. Only when every step is right can players accomplish the game. The final test scores demonstrate that the use of serious games improves students' study outcomes and contributes to improving knowledge retention (35).

Continuing medical education (CME) is an important part of medical education, especially for general practitioners. However, limited learning strategies together with their time-consuming disadvantage usually impede the further development of CME. In some cases, the use of technology creates more realistic situations by providing subjects with immersive experiences and finally achieving improved scores. Therefore, CME games have the potential to make up traditional methods tedious and sporadic. At present, the objectives of most CME games are to verify their effectiveness and satisfaction (29–31). By comparing the game with article reading, a traditional continuing education, researchers demonstrated that serious games functioned in a more effective, pleasant, and evidence-based way (29). Even though the outcome of serious games sometimes is not encouraging as hoped, it is at least as effective as a traditional educational activity and is proposed to be a feasible option for large-scale CME (31).

The advantages of using serious games in education not only include enriching pedagogical formats, promoting students' engagement, and enhancing their learning outcomes effectively as mentioned earlier, but also have the potential to reduce expensive bedside teaching and optimize the design of medical practices (36, 40, 41). Despite these benefits, challenges and limitations remain. The application of serious games fails to generate ideal results in regard to transferring learners' clinical reasoning skills acquired in serious games to other cases addressing similar clinical problems (42). Furthermore, the feasibility and effects of serious games require a match between task complexity and the learner's competency level in some cases because a game may not be effective for novices but be useful for experts, which is also known as the "expertise reversal effect" (43). Therefore, measures should be taken to ensure that junior trainees learn when playing the game. Cost and efficiency are important factors that need to be considered while developing a feasible game for teaching activity since excellent software created by third-party designers even costs thousands of dollars. In addition to the economic expenditure, the time needed for training instructors as well as the need for technical support and resources are common barriers that need to be solved (1). In addition, some research designs concerning serious games in teaching activity are not following the principles of randomization and control, which makes it difficult to exclude other factors influence. Notwithstanding, we can see that some randomized controlled trials are conducted continually. These trials confirmed the positive implications of serious games on teaching knowledge (37, 44).

4. Gamification in medical education

Gamification is another strategy of game-based learning, which can be described as the application of the characteristics and benefits of games to real-world problems and a process of game-thinking and game mechanics to engage users and solve problems (13, 14). The field of gamification in medical teaching activity is innovative and developed constantly. Even though gamification and serious game have some analogous characteristics and conceptual overlap, there are some means to distinguish them. The easiest and most direct method is removing the game elements to see whether the learning activity still functions. Also, different from the combination of learning and game goals in serious games, gamification is a design technique that typically layers game goals on top of learning goals to motivate engagement and constructive behavior of participants (45).

It has been recognized that the use of gamification in medical education is significant and salutary. Meanwhile, the area of related study is expanding. Several published articles comprehensively summarized its advantages such as enhancing collaboration and increasing the engagement of students, improving their earning analytic and clinical decision-making capacity, as well as offering them opportunities for deliberate practice in clinical reasoning (13, 46). In light of its profound influences, gamification has been widely applied in various medical disciplines and different learning stages, particularly for the millennial learner, to promote significant

TABLE 2 Gamification in medical teaching activity.

Game name	Filed	Game type	Country and year	Propose	Advantages	Reference
NO	Microbiology	Online question bank	America, 2022	To promote students meaningfully engagement and increase their knowledge base	Improving students class exam scores and engagement.	(47)
NO	Microbiology	Checkerboard game	India, 2021	To assess the perception of students regarding game in enhancing learning process.	Fostering learning process and cognition of medical students in the microbiology course.	(48)
SIDRA	Anatomy of locomotor system	Online game	Spain, 2020	To engage students and improve their educational performance	Better student responses and academic performance.	(49)
NO	Anatomy	Board game	Thailand, 2021	To analysis students participation and experiences around the gamification process	Creating a fun-filled and interesting learning environment, improving students performances significantly.	(50)
Kahoot	Immunology	Online game	Sri lanka, 2022	To explore the medical students' perception using gamification teaching	Increasing the focus, understanding of the subject, helping retain knowledge, motivating students to learn and keeping them active throughout.	(51)
Stud2yBuddy	Dermatology	Card-based board game	UK, 2019	To develop an effective interactive resource, improve students confidence, encourage peer feedback and self-assessment of student in finals revision.	Increasing students confidence in revising dermatology.	(52)
Table-top	Emergency	Offline game	Spain, 2022	To evaluate the learning process of students and measure their knowledge improvement.	Improving medical studies and promoting knowledge retention	(53)
NO	Mental illness	Online game	Iran, 2019	To evaluate the implementation of a mental gamification and its efficacy on students.	Shaping the students' satisfaction and promoting teaching effect.	(54)
Escape boxes	Emergency	Offline game	America, 2022	To determine the effectiveness of the game in emergency medicine	Promoting teamwork and communication, improving didactics ratings	(55)
Spaced education (SE)	Anatomy, histology, cardiology and endocrinology	Online game	America, 2012	To investigate the effectiveness of the game on improving students knowledge	Having the potential to assess students knowledge and acting as an effective and well-accepted teaching means	(56)
Kaizen-IM software	Graduate education	Online game	America, 2013	To assess acceptance of the game and to determine retention of information presented to participants	Teaching critical medical concepts	(57)
East EMWars	Emergency	Longitudinal game	America, 2022	To investigate the impact of the game in emergency medicine residency training	Improving residents motivation, engagement, and challenge level	(58)
NO	Geriatric medicine	Electronic questionnaire	Switzerland, 2021	To evaluate the feasibility of the game on polypharmacy	Enhancing the attitudes and understanding of students	(59)
Escape room	Clinical practice	Offline game	America, 2019	To measure the effectiveness of the game intervention	Improving players clinical capacity and providing them with the opportunity to document event reports in real time	(60)

teaching outcomes and to further evaluate its effectiveness, which is listed in Table 2.

As an important supplement to medical curriculums, gamification has been widely used by a variety of specialties in undergraduate courses, postgraduate teaching, and resident medical education. In most cases, gamification changes traditional tedious formats of teaching activity in the undergraduate stage. Microbiology is one of the core courses in undergraduate medical education (UME) that contribute to understanding and diagnosing various clinical diseases. The application of gamification in

microbiology course is a breakthrough and an innovative attempt. By exploiting a supplemental question bank that integrates game elements and clinical pearls, Walker et al. explored the effectiveness of gamification in microbiology teaching (47). In brief, the question bank resembles "tutor mode" to deliver and provide content, and students need to answer related questions to obtain the score. The composite measures include questions answered, their accuracy, and the time of response of players. This gamification design leads to higher class exam scores and increases students' basic knowledge (47). In addition, the utilization of checkerboard games also fosters the learning process and students' cognition in microbiology courses (48). A well-designed gamification process is likewise crucial for creating a fun-filled atmosphere and platform to further enhance the learning experiences and educational performance of medical students in the anatomical curriculum (49, 50).

As for other subjects in the undergraduate stage, such as immunology and dermatology, gamification of learning shows meaningful results in terms of maintaining students' attention and keeping them in an active state throughout the course (51, 52). Kahoot represents an emerging game-based learning platform that can provide timely feedback for players and is extensively applied for formative assessment during remote teaching of immunology. In the game, participants compete with each other for the correct answer and response time, and based on these performances, the overall winners will be displayed on scoreboards (51). Stud2yBuddy is a card-based board game with four categories that incorporates peer feedback and self-assessment and has the potential to offer the opportunity for improving students' content understanding (52). Moreover, gamification of learning can also shape students' satisfaction and increase their study motivation in teaching activities (53–55).

As an innovative approach for enhancing teaching effects, gamification also plays a significant role in postgraduate medical education. An online game, termed "spaced-education," covers both preclinical and clinical domains and functions by incorporating adaptive game mechanics into an evidence-based format (56). In the game, students repeated answers to given questions according to their response accuracy to optimize long-term retention of learning. It becomes a valid and reliable tool for assessing students' knowledge and represents a well-accepted way of teaching core content (56). Furthermore, gamification together with spaced repetition studies is gradually becoming an optimal complementary method to encourage medical education and manifest obvious benefits in promoting the retention of clinical understanding (61). Likewise, the application of gamification gains well-acceptance and yields positive implications among residents (57–60).

In the context of the COVID-19 pandemic, O'Connell et al. developed a novel virtual game for obstetric and gynecology teaching. The game contains a warm-up activity and several rounds of rapid-fire questions and cases, and the main purpose of each round is to test players' knowledge about obstetric and gynecological care. This gamification attempt boosts resident education and engagement due to its entertaining, effective, and educational concepts (62). In addition, some optimized suggestions and solutions have been proposed for better designing gamification in the field of medical education during the COVID-19 era. First, teaching how to play the game by dividing lessons into smaller ones is a feasible method to develop short tests for tracking students' progress. Second, educators should take into account how students work together, their true capacities, and their preferences. Third, test design is an important element that can build students' knowledge and should be carefully treated. Furthermore, the use of different game platforms can motivate better interaction of players to improve their competition sense and sociability. Finally, future investigation also should focus on how and under what conditions gamification can maximally exert its promoting education functions effectively (63, 64).

In short, the application of gamification in medical teaching activity is promising and attractive because of its potential to provide more intuitive user experiences, solve the difficulty of remote teaching, and improve learners' engagement and motivation (65–67). Nevertheless, it is worth noting that the theoretical framework specific to medical education is still lacking, and optimized strategies as mentioned earlier deserve to be considered and further evaluated.

5. Discussion

Game-based learning activities can create a fascinating learning environment for students to improve their study outcomes. The benefits of GBL on learners include enhancing their collaborative awareness, providing them with opportunities for active learning to better solve clinical problems, and improving their clinical reasoning and decision-making skills. Furthermore, GBL can enable educators to explore novel and feasible teaching strategies, which contribute to the reformation of current didactical activities. Therefore, the application of serious games and gamification in medical education is meaningful.

Despite the obvious benefits, disappointing results and weaknesses remain. For example, GBL cannot yield significant outcomes in short-term gains and long-term knowledge retention sometimes (68). Therefore, how to better use recreational factors to promote teaching activity is a problem we need to solve. Moreover, there is no standardized evaluation system to measure the specific impact of GBL on students' performance and pedagogical outcomes. Many of the published works in medical education mainly converged on the engagement level and satisfaction of participants as well as the changes in knowledge score from pre-test to post-test, whereas largely ignored advanced learning objectives such as long-term knowledge gain. In the Kirkpatrick Model, the evaluation system is categorized into four levels: how participants are reacting to the program, what they can learn from the program, whether and how the program changes their practice behavior, and the profound influence of the program on participants (69, 70). In this regard, further studies should focus on assessing participants' practice behavior and the profound influence of GBL on students, which resembles the third and fourth levels of the Kirkpatrick Model. Also, most studies regarding GBL in medical education were conducted based on small sample size, and in the future, the results should be validated by further multicentric studies. As for the cost of game development, researchers should synthetically consider to best achieve the professional result of which students are used to. Finally, games are typically not considered mainstream material in medical teaching, and it is

important to improve their popularizing rate and explore their potential explanatory mechanisms.

6. Conclusion

At present, medical education is rapidly evolving. Meanwhile, game-based learning has been gradually used for education, and several innovations have emerged. The emergence of serious games and gamification provides alternative approaches for educators to improve the medical teaching process. In most conditions, these teaching formats are well-received by learners and can create an immersive experience for students, considered effective, engaging, easy to understand, interesting, and educational in comparison with traditional teaching activities. Multiple teaching modalities of GBL also contribute to its further application, such as card, board, and even digital games using modern technology. As such, GBL has been recognized as a potential tool for enhancing medical education.

In summary, as a novel and promising teaching method, GBL has gradually become a popular addition to medical education curricula. It functions by providing the possibility of combining learning activities such as feedback, testing, and spaced repetition with active participation and autonomy as well as positive experiences for students. Designing a more effective GBL has the potential to bring an immersive experience for medical students and improve their study outcomes.

Author contributions

HQ and XZ offered the main direction and significant guidance of this manuscript. MX and YL drafted the manuscript and made the tables for the manuscript. YZ and RX critically revised the manuscript. All authors approved the final manuscript.

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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EDITED BY
Christiane Stock,
Charité Medical University of Berlin, Germany

REVIEWED BY
Xiaomin Song,
BeiGene, China
Rosemary M. Caron,
University of New Hampshire, United States

*CORRESPONDENCE
Roxana Dev Omar Dev
✉ rdod@upm.edu.my

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Blended learning in physical education: A systematic review

Chen Wang, Roxana Dev Omar Dev*, Kim Geok Soh, Nasnoor Juzaily Mohd Nasirudddin, Yubin Yuan and Xueyan Ji

Department of Sports Studies, Faculty of Educational Studies, Universiti Putra Malaysia, Selangor, Serdang, Malaysia

This review aims to provide a detailed overview of the current status and development trends of blended learning in physical education by reviewing journal articles from the Web of Science (WOS) database. Several dimensions of blended learning were observed, including research trends, participants, online learning tools, theoretical frameworks, evaluation methods, application domains, Research Topics, and challenges. Following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), a total of 22 journal articles were included in the current review. The findings of this review reveal that the number of blended learning articles in physical education has increased since 2018, proving that the incorporation of online learning tools into physical education courses has grown in popularity. From the reviewed journal articles, most attention is given to undergraduates, emphasizing that attention in the future should be placed on K-12 students, teachers, and educational institutions. The theoretical framework applied by journal articles is also limited to a few articles and the assessment method is relatively homogeneous, consisting mostly of questionnaires. This review also discovers the trends in blended learning in physical education as most of the studies focus on the topic centered on dynamic physical education. In terms of Research Topics, most journal articles focus on perceptions, learning outcomes, satisfaction, and motivation, which are preliminary aspects of blended learning research. Although the benefits of blended learning are evident, this review identifies five challenges of blended learning: instructional design challenges, technological literacy and competency challenges, self-regulation challenges, alienation and isolation challenges, and belief challenges. Finally, a number of recommendations for future research are presented.

KEYWORDS

blended learning, physical education, sports, educational technology, learning strategies

1. Introduction

The integration of multiple technologies into traditional instruction has attracted enormous attention and offered numerous research avenues over the years. For instance, influential studies have confirmed the benefits of blended learning. According to Müller and Mildenberger (1), the definitions of blended learning most commonly used in scientific publications are those by Graham [(2), p. 5]: "blended learning is a combination of face-to-face and computer-mediated instruction" and by Garrison and Kanuka (3): "thoughtfully integrate the face-to-face learning experience in the classroom with the online learning experience." Therefore, blended learning in this review includes technology-supported

learning with the exception of fully online and fully face-to-face instruction. According to the sequence of integrating traditional classroom-based and online instruction, blended learning can be classified in the forms of blended, hybrid, flipped, or inverted. Despite the forms of blended learning, the use of blended learning has greater potential for transferring content into practice (4) and improves the quality and quantity of interaction between teachers and students (1), flexibility (5), learning engagement (6), and differentiated instruction (7) in classrooms.

To date, blended learning models are considered to be the most widely adopted instructional model by educational institutions as they are regarded as effective in providing flexible, timely, and continuous learning (8). The models have proven to be an upgrade from traditional learning models and fully online learning models as blended learning models combine the advantages of online and face-to-face learning (9). As a result, blended learning approach is referred to as the "new traditional model" or the "new normal" due to its advantages in optimizing the teaching and learning (10).

The significance of physical education in contemporary schooling is recognized internationally. Yang et al. (11) note that in addition to motor skills and physical fitness, physical education has a positive impact on students in several dimensions, such as their personal and social skills, patience, self-esteem, and self-confidence (12–14). In traditional teaching models of physical education, students are placed in a relatively passive position in order to receive knowledge and skills provided by the curriculum and the teaching content is inflexible as it ignores student differences and limits the opportunities for individual instruction and remediation by teachers (15, 16). To address the issue with the traditional teaching models of physical education, López-Fernández et al. (17) suggest blended learning models to provide students with personalized learning opportunities to optimize the quality of their learning in physical education classes, as well as to motivate students to learn.

A systematic review is necessary to understand current research situations of blended learning in physical education. Even though there have been considerable studies on blended learning in physical education, a systematic review of blended learning in this field is limited. To date, only one systematic review investigating the effectiveness of blended learning in higher physical education has been published (18). Therefore, this study aims to synthesize and analyze the findings to describe the current state and research trend of blended learning in physical education, and thus establish new directions for future research. This study was driven by the following research questions:

1. What are the research trends in blended learning in physical education?
2. Who are the main participants?
3. What are the main online learning tools?
4. What are the theoretical frameworks and evaluation methods used in blended learning in physical education?
5. What are the application domains and Research Topics involved in blended learning in physical education?
6. What are the reported challenges of blended learning in physical education?

2. Methodology

2.1. Search process

This systematic review follows the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (19). The search on the Web of Science (WoS) electronic database for the articles began in July 2022 and concluded in August 2022. WoS electronic database was chosen because of its high reputation and reliability in investigating leading articles. A search string was developed according to researchers' understanding and knowledge in the field of blended learning and physical education, as well as relevant blended learning and physical education search strings reported in other studies such as in Rasheed et al. (8) and Yang et al. (11). The search strings: (blended learning OR blended course OR hybrid learning OR hybrid course OR flipped learning OR flipped learning OR flipped classroom) AND (physical education OR sport* OR physical activity* OR exercise), were inserted in the advanced search query of the Web of Science database. The field option was then specified as a topic and restricted the search to the Social Sciences Citation Index. Then, the references of the papers included in this study were reviewed to ensure that the selected papers answered the six research questions of this review.

2.2. Eligibility criteria

To be considered for inclusion in this review, selected journal articles had to meet the following criteria: (a) define blended learning as the incorporation of traditional face-to-face and online learning, (b) related to blended learning in sports or physical education, (c) empirical study of SSCI indexing, and (d) published in English. On the other hand, the exclusion criteria included: (a) articles with sole concern on the face-to-face portion of blended learning, (b) book chapter reviews, meeting abstracts, reports, and review articles, (c) non-English articles, and (d) unavailable full-text articles.

2.3. Study selection

A total of 531 journal articles were identified from the Web of Science database. A total of 256 duplicate articles were removed after considering the articles following the inclusion and exclusion criteria. Then, using the EndNote reference management software, a database of 135 articles with their titles, abstracts, and full text was created. The articles were carefully read and 22 articles were found pertinent to this review. Figure 1 shows the filtering process of this review based on the PRISMA statement (19).

2.4. Data extraction and quality assessment

The data extraction process included the identification of (a) the article's author, nationality, and publication year, (b) participants (i.e., K-12 students, undergraduates, teachers, and

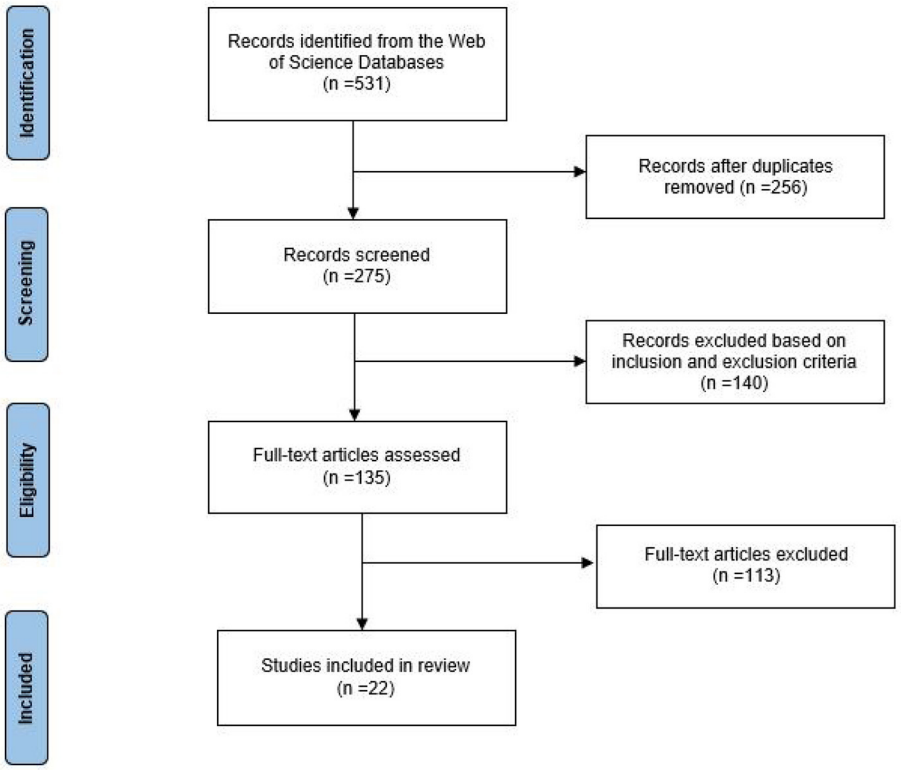

FIGURE 1
A review process based on the PRISMA statement.

others), (c) online learning tools (i.e., learning platforms, learning software, recorded lectures, online learning materials, and others), (d) theoretical frameworks and evaluation methods (i.e., interviews, questionnaires, tests, and other methods), (e) application domains (i.e., basketball, football, badminton, and other courses) and Research Topics (i.e., perceptions, satisfaction, learning effects, and other items), and (f) challenges.

As the reviewed articles differed in research design, a quality assessment tool developed by Rowe et al. (20) that has been proven to be a useful tool for assessing qualitative, quantitative, and mixed methods was utilized (21). The tool assesses five important methodological aspects of a study, namely the background or literature review, sample, study design or methodology, outcome measures, and conclusions (see Table 1). The total score ranges from 0 to 5, with the higher scores representing better methodological quality. Articles scoring 4 or 5 are considered to be high in quality, articles scoring 3 are considered to be of moderate quality, and studies scoring between 0 and 2 are considered to be low in quality. In this review, two trained reviewers independently assessed the quality of the article, with disagreements resolved by the third reviewer. All 22 articles received a score between 4 and 5, indicating their high methodological quality.

3. Results

This part reports the current state of blended learning in physical education and the key findings by addressing the six research questions of this review. The summary of the characteristics of the 22 studies involved is shown in Table 2.

3.1. Research trends

The first article on blended learning in physical education was published in 2011. However, since then, the research in this field was limited with zero publications in 2012, 2013, 2014, 2015, and 2017, and only one publication in 2016. However, beginning in 2018, physical education researchers have become increasingly interested in blended learning, with the number of articles reaching a peak in 2020. Journal articles published before August 2022 were also included. However, the number did not represent the accurate situation for the entire year of 2022 because this review concluded in August 2022. The graph of the trends in research on blended learning in physical education is shown in Figure 2.

Based on the number of publications on blended learning in physical education from 2011 to 2022, studies conducted in China accounted for 41 per cent of the total number of publications ($n = 9$). From the nine studies, Lin, Hsia, and Hwang authored five studies (27, 29, 30, 36, 39). The next highest number of publications on blended learning in physical education was conducted in Spain ($n = 6$) and the United Kingdom ($n = 3$), while each of the remaining studies was conducted in countries such as the United States, Singapore, Australia, and Ireland.

TABLE 1 Methodological quality assessment tool.

Criterion	Score
1. Background/literature review:	
A. Detailed?	1
B. Limited?	0
2. Sample:	
A. Well-described?	1
B. Poorly described?	0
3. Study design or methodology:	
A. Clear?	1
B. Not clear?	0
4. Outcome measures:	
A. Valid/reliable and well-described?	1
B. Not valid/reliable, poorly described or not identified?	0
5. Conclusions:	
A. Supported by the study results?	1
B. Not supported by the study results?	0
Methodological quality	
High	Moderate	Low
Total score ≥ 4	Total score = 3	Total score ≤ 2

*Total score = sum of individual scores.

3.2. Participants

This review identified a total of 3,543 subjects enrolling in the 22 reviewed articles, with 2 (34) to 602 participants in each study (22). It is found that the majority of research subjects were undergraduate students (n = 15). A total of 5 articles reported detailed information about the majors of their participants and the locations of their degree programs, namely undergraduates of exercise science from Griffith University (23), undergraduates of physical education from the University of Granada, Organization of Educational Centers (Degree) (24), undergraduates of Pablo de Olavide University, Physical Activity and Sports Science (Degree) (25), undergraduates of sports management from San Antonio de Murcia University and Pablo de Olavide University (37), and undergraduates of sport and exercise science from the Edge Hill University (41). Out of the 22 reviewed articles, 3 articles focused on teachers, 1 article focused on teachers and undergraduates (37), and 3 articles focused on K-12 students. Among K-12 students, only primary and secondary students were included (32, 33, 35).

3.3. Learning tools

A variety of learning tools were used in the blended learning activities of physical education. Nine journal articles focused on learning platforms, such as Moodle, Wisdom Master Pro, TronClass, and Superstar as learning tools. Online learning materials, including online lectures, online documents, and online websites were studied in six articles. Learning software was mentioned in three articles, while one article used recorded lectures as the primary learning tool. Also, there were articles combining two learning tools (32, 34). The use of a learning platform and robots as learning tools was also studied in an article (35). Nevertheless, four articles did not report any learning tools.

3.4. Theoretical frameworks and evaluation methods

Blended learning is a pedagogical framework based on multiple theories of teaching and learning. This review discovered that the theories presented in the articles include self-determination theory (SDT) (22, 31), WSQ-based flipped learning model (29), ARQI-based flipped learning model (30), constructivism theory (34, 37), hybrid learning theory (35), post-humanism theory (37), cognitive apprenticeship and reflective practice theory (36), ICRA-based flipped learning model (39), and 3C model (42). However, of the 22 articles included in this review, 12 articles did not report a theoretical framework that was used to guide their research and teaching practice.

In terms of evaluation methods, 11 articles on blended learning in physical education used only 1 assessment method, 5 articles used 2 assessment methods, and 6 articles used 3 or more assessment methods. Questionnaires were employed by the greatest number of articles (n = 15), with 3 of them open-ended questionnaires (23, 25, 41). The evaluation methods were followed by tests (n = 11) and interviews (n = 10). Other evaluation methods such as lesson observation, field notes, document analysis (34), and reflective blogging (37) were also used.

3.5. Application domains and research topics

The range of applications for blended learning in physical education was diverse. There were 10 articles involving sports courses such as the Physical Activity and Wellness course (22), Sports Coaching course (23), and Sports Management course (40). There were also two articles on theory courses (37, 42). In addition, most of the current blended learning articles explored dancing (27, 29, 30, 38), followed by basketball (28, 31), football (26), Wushu (35), billiards (36), and badminton (39). A total of seven articles did not refer to specific areas of the physical education (17, 24, 25, 32–34, 41).

This review discovered that many articles investigated more than one Research Topic, and the totals exceeded the number of reviewed articles. As a result, the current review grouped the Research Topics of the 22 articles on blended learning in physical education into seven categories. The first category is the perceptions of students or teachers. This topic was investigated in 13 articles and was the most important concern of the blended learning community. The second category was the effects of blended learning in physical education on student learning. This topic was investigated in 12 articles. A total of 6 investigated the third category of blended learning in physical education which is

TABLE 2 Characteristics of the studies examined in the preset review.

References	Country	Participants	Sample size	Learning tools	Theoretical framework	Evaluation methods	Application domains	Research Topics
Sidman et al. (22)	USA	Undergraduates	602	Online Lecture	Self-determination theory (SDT)	Questionnaire	Physical activity and wellness	Exercise motivation
Reddan et al. (23).	Australia	Undergraduates	35	Online learning materials	/	Test/open-ended questionnaire	Sports coaching	Learning effects/perception
Hinojo-Lucena et al. (24)	Spain	Undergraduates	131	Moodle learning platform	/	Test	Physical education	Learning effects/attendance
Otero-Saborido et al. (25)	Spain	Undergraduates	66	/	/	Open-ended questionnaire	Physical education	Design and validate self-assessment tool
Griffiths et al. (26)	UK	Undergraduates	147	Online learning	/	Questionnaire/ interview	Football	Perception/skills and qualifications/career development
Lin et al. (27)	China	Undergraduates	114	Wisdom Master Pro 2.0 learning platform	/	Test/questionnaire/interview	Dance	Learning effects/self-efficacy/perception/satisfaction
Chiang et al. (28)	China	Undergraduates	326	Basketball learning software	/	Test	Basketball	Learning effects
Hsia et al. (29)	China	Undergraduates	173	Wisdom Master Pro 2.0 learning platform	WSQ-based flipped learning model	Test/questionnaire /interview	Dance	Learning effects/learning motivation/self-efficacy/satisfaction/task load/perception
Hsia and Hwang (30)	China	Undergraduates	129	Evernote learning software	ARQI-based flipped learning model	Test/questionnaire /interview	Dance	Learning effects/self-efficacy/task load/perception
Koh et al. (31)	Singapore	Teachers	8	Online website	Self-determination theory (SDT)	Interview	Basketball	Perception
Lucena et al. (32)	Spain	K-12 students (primary and secondary)	119	Videos + learning software	/	Questionnaire	Physical education	Learning effects

(Continued)

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TABLE 2 (Continued)

References	Country	Participants	Sample size	Learning tools	Theoretical framework	Evaluation methods	Application domains	Research Topics
Segura-Robles et al. (33)	Spain	K-12 students (secondary students)	64	/	/	Test	Physical education	Learning effects/psychological needs in exercise/sport motivation/satisfaction
Sargent and Casey (34)	UK	Teachers	2	Online materials and platforms	Constructivism theory	Interview/lesson observation/field notes/document analysis	Physical education	Perception
Yang et al. (35)	China	K-12 students (primary students)	80	Learning platform + robots	Hybrid learning theory	Test/questionnaire	Wushu	Learning effects /learning Interest/attitude
Lin et al. (36)	China	Undergraduates	75	Learning software	Cognitive apprenticeship and reflective practice theory	Test/questionnaire /interview	Billiards	Learning effects/motivation/self-efficacy
López-Fernández et al. (17)	Spain	Teachers	174	/	/	Questionnaire	Physical education	Perception
Calderón et al. (37).	Ireland	Teachers/undergraduates	123	Recorded lecture	Constructivism theory and post-humanism theory	Interview and reflective blog	Physical education theory (PET) curriculum	Perception
Chao et al. (38)	China	Undergraduates	290	TronClass learning platform	/	Test/questionnaire /interview	Dance	Learning effects, satisfaction and perception
Lin et al. (39)	China	Undergraduates	74	Learning platform	ICRA-based flipped learning model	Test/interview	Badminton	Learning effects and perception
Gallardo-Guerrero et al. (40)	Spain	Undergraduates	370	Online document	/	Questionnaire	Sports management	Interaction /perception
Finlay et al., (41)	UK	Undergraduates	203	/	/	Open-ended questionnaire	Physical education	Satisfaction and perception
Liu et al. (42)	China	Undergraduates	238	Superstar learning platform	3C model	Questionnaire	Physical Education Theory (PET) curriculum	Satisfaction

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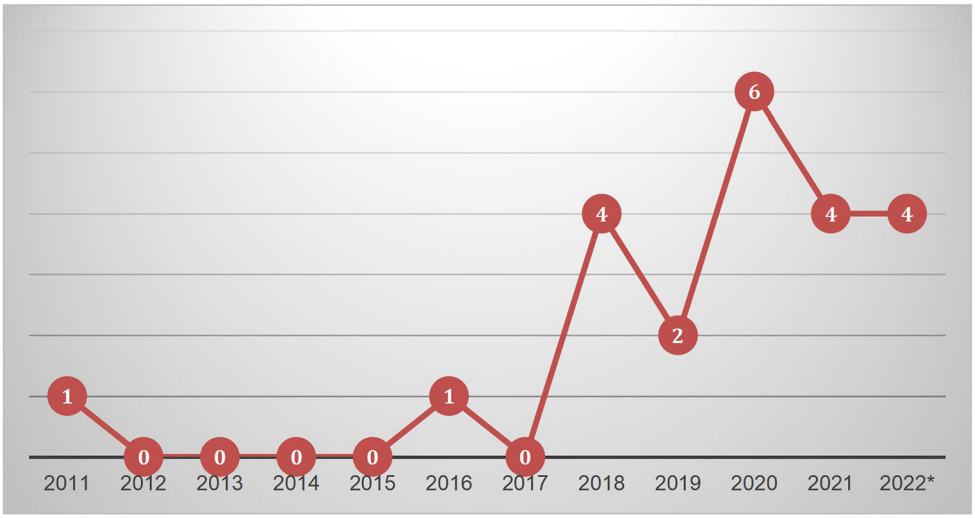

FIGURE 2
Number of articles published by year.

student satisfaction with blended learning. In addition, 4 articles examined the student motivation (22, 29, 33, 36) and self-efficacy (27, 30, 36), while 2 articles studied task load. Other Research Topics such as attendance (24), self-assessment tools (25), skills qualifications and career development (26), psychological needs (33), learning interest and attitude (35), and interaction (40) were also discovered.

3.6. The challenges of blended learning in physical education

This review identified five categories of challenges of blended learning in physical education. They were instructional design challenges, technological literacy and competency challenges, self-regulation challenges, alienation and isolation challenges, and belief challenges (see Table 3). First, instructional design challenges (n = 6) involved a set of challenges related to scientific planning and rationalization of all aspects of the teaching and learning process in advance, based on student learning characteristics and teacher teaching styles. The second category was technological literacy and competency challenges (n = 5), which relates to a range of challenges associated with student/teacher proficiency and competence in the appropriate use of technology for teaching and learning. The third category, self-regulation challenges (n = 2) involved a series of related student behaviors that prevent students from self-regulating the emotions, thoughts, and actions they plan to take in achieving their learning goals. Belief challenges (n = 2) included negative attitudes and perceptions of teachers or students about the use of technology for teaching or learning. Finally, alienation and isolation challenges (n = 1) involved a set of associated emotional discomforts suffered by teachers or students when teaching or learning outside of traditional classrooms, mainly caused by loneliness and isolation from others.

TABLE 3 The challenges of blended learning in physical education.

Challenges	References
Instructional design challenges	(23, 26, 29, 31, 34, 38)
Technological literacy and competency challenges	(17, 23, 29, 32, 42)
Self-regulation challenges	(29, 42)
Belief challenges	(17, 38)
Alienation and isolation challenges	(17)

4. Discussion

4.1. Summary of findings and discussion

In this systematic review of the adoption of blended learning in physical education, 22 journal articles retrieved from the Web of Science (WOS) database were analyzed and grouped according to research trends, participants, learning tools, theoretical framework, evaluation methods, application domains, Research Topics, and challenges. The publication trend shows that there has been a growing interest in blended learning in physical education since 2018. This indicates that researchers have recognized the role of technology in physical education and have sought to apply technology in physical education to meet student educational needs based on the current challenges and technological teaching resources offered by contemporary society (32). In addition, the paucity of high-quality literature suggests that research on blended learning in physical education is still in its infancy around the world. Of the 22 articles in this review, 9 were conducted in China, 6 in Spain, and 3 in the UK. Each of the other articles was published in countries such as the USA, Singapore, Australia, and Ireland. Also, previous research supports the view that studies on blended learning in skills-based subjects are very limited and somewhat disconnected (27, 31, 43).

For the participants, the majority of blended learning journal articles in physical education have focused on undergraduates. This is in line with the study by Yang et al. (11) which found that researchers were more concerned with mobile learning in higher physical education. However, only a limited number of articles investigated K−12 students and teachers separately. This review discovers that blended learning can be a challenge for K−12 students as they have poor self-control and are unfamiliar with the operation of online learning platforms, making it difficult for them to watch instructional videos independently before class. As a result, some articles report several suggestions for applying blended learning in the K-12 educational setting, including determining the duration of online learning based on student attention spans (44), designing simple and streamlined online courses to create organized learning environments that enable students to improve user experience and reduce cognitive load (45), connecting online learning content to student experiences (46), creating study groups in which the teacher sets a theme and the students participate in the learning in a group form to develop the awareness of active participation and the ability to collaborate (47), providing personalized support (48), and learning through games to develop skills and knowledge related to course objectives (49). One prominent suggestion by the reviewed articles is that applying blended learning allows for the facilitation of various types of interactions (50). Among them, student-student interaction refers to peer support and collaborative learning, student-teacher interaction consists of evaluation, motivation, guidance, and prompt feedback (51), student–online learning content interaction is the process of intellectual interaction with learning content, to promote students' learning (52), and student-interface interaction refers to the interaction between students and the technology used to deliver educational content (53).

In addition, there is a limited number of articles on blended learning in physical education focusing on teachers. This may be because the selection of teachers as subjects for the study is challenging for several reasons. For example, the sample size may be too small for quantitative analysis and some teachers may be reluctant to embrace new teaching models. Nevertheless, technologies, through blended learning, offer many new opportunities for teaching. Besides that the use of blended learning could improve teachers' attitudes toward the application of technology, and it could also enhance their ability to apply technology to physical education, which is crucial for their professional development (54). Therefore, future blended learning papers in physical education should place greater emphasis on the teacher community.

Blended learning as an innovative pedagogical model requires the application of emerging methods in practice to meet specific pedagogical requirements (55). This review observed that teachers use different teaching platforms and online learning resources when incorporating blended learning in physical education in order to meet their pedagogical goals. The frequency of "learning platform" ranked highest among the selected studies, followed by "online learning materials" and "learning software." With the development of educational technology, many student-centered learning platforms (e.g., Moodle, Superstar) are adopted by teachers in different educational institutions. These learning platforms are supported by teachers because they are powerful, easy to use, and can meet the common needs of both teachers and students (56). In addition, online learning materials which include online lectures, online documents, and online websites have also become teachers' choices. Compared to online learning platforms, online learning materials are richer in content and more diverse in learning formats. Teachers can select appropriate materials according to their student learning interests and practical needs (57). Self-developed learning tools or learning materials appropriate for the delivery of the courses are also created by teachers. One article developed and applied a robot (35), one article used recorded lectures (37), and a total of three articles used instructional software (e.g., basketball teaching mobile application) as the primary learning tool for learning activities (28, 32, 36). In general, while research on blended learning in physical education prior to 2020 on learning tools was homogeneous, the form diversifies as teachers begin combining two learning tools to produce better learning outcomes beginning in 2020, with the increased number of blended learning studies in physical education.

The theoretical framework is an essential component of disciplinary inquiry as it provides researchers with a strong argument for the significance of a particular research question and guides the analysis and interpretation of the data collected (58). The variety of theoretical frameworks found in reviewed articles indicates that blended learning in physical education is still in the stage of theoretical exploration, especially with twelve articles failing to specify a theoretical framework or a theoretical model used in the studies. The most commonly cited theories in this study are the self-determination theory (SDT) (22, 31) and the constructivist theory (34, 37). The self-determination theory asserts that individual development and progress are achieved through the satisfaction of three basic psychological needs: autonomy (self-identity and autonomy of choice), relatedness (being loved and interacting), and competence (being perceived as effective and capable). Meeting these three needs in a learning task will significantly enhance students' intrinsic motivation (14). This is because, in blended learning, students can determine their own learning time and pace based on their preferences (autonomy) and individual learning levels (competence). Blended learning also allows for collaborative learning that provides a highly interactive learning environment that meets student needs for relevance (relatedness). In short, many studies support the existing literature that blended learning environments have a positive impact on students' cognitive learning outcomes and "needs" for competence, autonomy, and relatedness (59, 60).

On the other hand, constructivism, upholding the constructivist theory, believes that students do not passively acquire knowledge, but actively construct new understanding and knowledge through personal experience and social discourse and combine new information with existing knowledge (61). Blended learning emerged to overcome the disadvantages of passive learning in traditional physical education learning models and enhance students' learning experiences and build problem-solving skills for further practice by optimizing the combination of various learning modes. Applying constructivist theory to a blended learning environment, therefore, increases student interaction, learning efficiency, and quality (62). Post-humanist theory seeks

to provide a new epistemology that is non-anthropocentric and rejects dualism as a central (63). Guided by this theory, researchers have a better understanding of the significance of online and face-to-face instruction in blended learning. Also, according to post-humanist theory, when introducing blended learning in physical education, teachers need to design and use an integrated approach so that all instructional elements, as well as their components (e.g., online instructional materials and face-to-face activities), are interacting, thus enhancing the learning experience of students (37). This review also discovers another theory associated with metacognition that stresses helping students master and reflects on their current learning situations in blended learning in physical education so that they can improve their skill performance. It is cognitive apprenticeship. Cognitive apprenticeship is an instructional model proposed by American cognitive psychologists Collins, Brown, and Duguid in 1989 that emphasizes the importance of the process by which teachers transfer skills to students. The reflective practice focuses on students' reflection on their performance in an ongoing practice for personal development.

In traditional physical education learning models, students can only passively accept knowledge and skills in the classroom. To extend the learning time and space, a new approach involving virtual learning environments has been proposed, which is the Collaborative Cyber Community (3C) model (64). This model highlights the importance of interaction and collaboration in a virtual environment where students can gain motor skills and knowledge and teachers can develop the competencies to guide students in technology-related instruction. In addition, some theoretical frameworks based on the flipped learning model were also included in some of the reviewed articles, such as the watch, summary, and question (WSQ) flipped learning model, the annotation, reflection, questioning, and interflow (ARQI) flipped learning model, and the identification, communication, reflection, and analysis (ICRA) flipped learning model. The watch, summary, and question (WSQ) flipped learning model aims to guide students to mark key points and difficulties when watching instructional videos and summarize and ask questions during the before-class stage to promote students' understanding of the learning content (29). Even though students can focus on understanding the learning content through WSQ flipped learning model, there is a lack of practical experience and reflection on motor skills. In contrast, practice videos in the annotation, reflection, questioning, and interflow (ARQI) flipped learning model facilitate students' ability to observe their sports performance from a spectator's perspective and critically reflect on their motor skills and internal experiences, thus allowing them to improve their performance (30). Similarly, based on the educational theory of reflective practice, the Identification, Communication, Reflection, and Analysis (ICRA) flipped learning model was developed to improve the effectiveness of flipped sports learning and to create pedagogies that are more suitable for motor skill learning (39).

Evaluation for learning is a method used for instruction that provides feedback to students and teachers to promote learning and guide the next stage of action. Feedback includes informal feedback (e.g., immediate verbal comments on student performance or behavior) and formal feedback (e.g., written feedback given at the end of a test and recorded as evidence for use by the student and the organization). Evaluation to facilitate learning involves high-quality peer assessment of learning with each other and self-assessment, with the results used as a basis for deciding what will be learned in the future (65). In terms of evaluation methods, this review found half of the articles used formal feedback (tests), with questionnaires and interviews being the most common of the other feedback methods. Other evaluation methods such as lesson observation, field notes, document analysis (34), and reflective blogging (37) were also mentioned, indicating the diversity of assessment methods of blended learning in physical education research. In addition, it is worth noting that five articles in this review used two evaluation methods, while six articles used three or more evaluation methods. This is in line with the current research trend where mixed methods research is increasingly valued in social science research as it provides a better understanding of what blended learning entails and how it can support student learning in a variety of ways (66).

In terms of the application areas of blended learning in physical education, the dynamic domain was explored the most, indicating that at this stage, the research on blended learning in physical education is mainly focused on physical exercise, which is in line with the characteristics of physical education. Even though studies have been investigating blended learning in single sports, such as dance, basketball, football, and Wushu, the sports categories are limited and lack richness. Moreover, this review discovers that the physical education theory (PET) curriculum is currently a less studied (37, 42), probably because it is mainly conducted in higher education. However, it still has a vital role to play in the development of physical education. These two articles on the physical education theory (PET) curriculum only used interviews and questionnaires to investigate teachers' and students' experiences and satisfaction, so future research could use other research methods such as experimental and mixed methods to further investigate students' effectiveness and depth of perception. Furthermore, three articles explored both theoretical and pedagogical activity aspects of the physical education curriculum, such as the Physical Activity and Wellness (22), Sports Coaching (23), and Sports Management (40). The findings showed that there are different specificities to the use of blended learning, particularly the collaborative nature between students, experiential learning, the increased autonomy of students in their learning process, and the greater effect of critical thinking. Students receive more guidance and feedback from teachers in classroom activities, which is impossible to achieve with traditional teaching methods.

The findings from the dimension of the Research Topic reveal that perceptions ($n = 13$), as well as learning effects ($n = 12$) and satisfaction ($n = 6$), have been the main concerns of researchers when conducting blended learning studies, in addition to motivation ($n = 4$) and self-efficacy ($n = 4$). This is largely in line with the study by Chen et al. (67) which flipped the science classroom and found that the researchers were more concerned with the student's learning effects, as well as their perceptions and attitudes/motivation. This is justified because blended learning is a new approach for most teachers and hence, it is essential to examine the impact of a relatively

new pedagogical model on students' academic performance and perceptions. However, from the review of 22 articles, blended learning in physical education has generally met researchers' expectations. For instance, several studies mentioned the positive impacts of blended learning on students' learning effects, self-efficiency, interaction, and satisfaction (23, 27, 28, 32, 35), as well as their perceptions, motivation, and attitude (31, 36, 38, 41, 42). Furthermore, other topics such as the task load (29, 30), attendance (24), self-assessment tools (25), skills and career development (26), and psychological needs in sports (33) were also conducted. The findings show that blended learning in the field of physical education, though in a developmental stage, meets the expectations of researchers.

While the advantages of blended learning models in optimizing teaching and learning are evident in countless influential studies, incorporating technology into education also brings a degree of unease to students and teachers. The most common problem related to blended learning in physical education is the instructional design challenge. Researchers have recently begun to develop or use online technologies for teaching or training activities. However, due to its specificity and complexity, physical education is more difficult to design in blended learning than other academic learning activities (68). The research by Boelens et al. (69) identifies four key challenges in the design of blended learning environments: incorporating flexibility, facilitating interaction, facilitating the learning process for students, and creating an effective learning environment. The shortcomings of instructional designs such as a lack of variety in content (29, 34) and lengthy videos (23) are mentioned in several articles. Also, Liu et al. (42) report that students experience a sense of distance when involved in too many online learning activities. Tsai et al. (70) concur stating that online courses in blended learning should only be offered every 2 weeks so that students can learn on their own and, if they encounter problems, they can solve them through face-to-face interaction. Another challenge is the technological literacy and competency that have become necessary for teachers and students to pursue contemporary education. The findings of López-Fernández et al. (17), Lucena et al. (32), and Reddan et al. (23) emphasize the lack of literacy and competency among students and teachers in using technology. Liu et al. (42) mention that students are more conservative in enhancing their information-related skills, which affects their learning outcomes and satisfaction with the course. Similarly, Hsia et al. (29) highlight the need for blended-learning students to be technologically competent because incompetence with learning technology can be a barrier to students' success in blended learning.

Another challenge for students in blended learning is that they are expected to self-regulate their learning activities outside of face-to-face classes. Two articles specifically identified the types of self-regulation challenges, namely procrastination (42) and improper time management (29). It is worth noting that procrastination is considered a chronic habit of unnecessarily putting off things that need to be done (71). Students' procrastination behavior differs in traditional and blended models, as students in blended learning environments experience a more pronounced sense of transactional distance (8). Belief challenges in this study refer to the negative attitudes and perceptions of teachers or students regarding the use of technology for teaching and learning. As reported by Brown (72), the difficulties encountered in adopting technology may be seen as disruptive to teaching and learning. Teachers may think of blended learning as instruction that has two teaching sections to deal with. For example, some physical education teachers believe that blended learning meant extra work compared with traditional teaching (17). Chao et al. (38) also report that students are reluctant to accept pre-class preparation. Furthermore, past research has mentioned that student learning activities, such as homework and preparation before face-to-face lectures, are challenging due to the alienation and loneliness felt by students online. Similarly, the study by López-Fernández et al. (17) finds that alienation and loneliness were also a challenge for physical education teachers because they find it more challenging to establish social relationships, either between teachers and students or between students, in the blended learning model than in the traditional model. This view was confirmed by a previous study of blended learning in physical education, where teachers felt disconnected from students and expressed concerns associated with the potential lack of social relationships and learning opportunities for students in a virtual environment (73).

4.2. Limitation

First, this study is limited by the use of rich eligibility criteria and methodology to consider only high-impact journals. Referring to other databases such as Google Scholar, PubMed, or Scopus might have resulted slightly differently. Second, only articles written in English are chosen. Third, the definition of blended learning opted in this review is a combination of traditional and online learning, so articles that do not conform to this definition are excluded, such as those that only mention the face-to-face part of blended learning. Finally, the study only focuses on the application of blended learning in physical education, such as the development trends and the main findings of current research. Therefore, the results cannot be extended to all research dimensions. Nevertheless, this research should be adequate to provide a roadmap for future research on blended learning in physical education.

5. Conclusion and suggestions

According to the overall findings, blended learning is in the initial stages of its development in the field of physical education. This result can be seen in several ways. First, researchers around the world have tried to apply blended learning in physical education, but the number of high-quality studies is very limited. Second, the majority of participants in the studies of blended learning on physical education are undergraduates, and a limited number of studies have been conducted on other subjects such as K−12 students and teachers. This review also reveals that studies prefer to investigate proven learning tools and the materials chosen by teachers as pre-course learning materials based on their personal preferences. In terms of theoretical framework, half of the researchers in the field of blended learning in physical education tend to not mention any theoretical framework. In addition, many prefer adopting a single evaluation method, with questionnaires being the most common method. Moreover, the focus of most

journal articles on blended learning in physical education are on the preliminary aspects of blended learning research, namely perceptions, learning outcomes, satisfaction, and motivation. This leaves room for further research. This review also discovers that the most studied item in most articles on blended learning in physical education is dance. However, the majority of studies take a broad approach by not mentioning any specific item of physical education. Finally, the most common challenges for students and teachers revealed in this review are instructional design challenges, technological literacy and competency challenges, self-regulation challenges, alienation and isolation challenges, and belief challenges. In conclusion, this review provides a foundation for the future development of blended learning models by demonstrating the current status and development trends of blended learning in physical education.

Based on the results and discussion of the current review, several recommendations regarding blended learning in physical education are presented. First, it is necessary to improve the skills and perceptions of teachers. It is also evident that the researchers are very concerned about student perceptions of blended learning and learning outcomes. Most teachers and students identify instructional design and technological literacy and competence as their most obvious challenges. This implies that teachers need more training to improve their course design and management of online classes, including the use of multiple technologies as instructional support tools and the design of learning activities with various strategies at different stages of blended learning. To further explore the impact of blended learning on physical education, future research needs to focus on other populations (K−12 students, teachers, and educational institutions) and situations in other countries or regions. Future research should also focus on the application of blended learning in static physical education. Furthermore, it is recommended that the potential of blended learning in other sports be explored. In terms of the Research Topic, apart from the perceptions and learning effects, other aspects such as psychological needs and influencing factors should also be investigated.

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

Conceptualization, software, formal analysis, investigation, resources, and writing—original draft preparation: CW. Methodology: CW and YY. Validation, writing—review and editing, visualization, and project administration: CW and RO. Data curation: CW and XJ. Supervision: RO, KS, and NM. All authors have read and agreed to the published version of the manuscript.

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.

Publisher's note

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EDITED BY
Xuelei Ma,
Sichuan University, China

REVIEWED BY
Gitismita Naik,
All India Institute of Medical Sciences, Kalyani (AIIMS Kalyani), India
Prakamya Gupta,
National Health Systems Resource Center, India
Aparnavi Periasamy,
Kovai Medical Center and Hospitals (KMCH), India
K. A. Mogan,
National Institute of Epidemiology (ICMR), India
Aditya Singh,
Banaras Hindu University, India
Ricardo Adrian Nugraha,
Airlangga University, Indonesia

*CORRESPONDENCE
Bijaya Kumar Padhi
✉ bkpadhi@gmail.com
Kapil Goel
✉ drkapil123@gmail.com
Tareq Al-Ahdal
✉ tareq.al-ahdal@uni-heidelberg.de

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Impact of virtual continued medical education on carbon footprint and awareness of digital sobriety: A retrospective cross-sectional study among public health professionals in India

Aravind P. Gandhi[1], Bijaya Kumar Padhi[2]*, Kapil Goel[2]*, Amarjeet Singh[2], Om Prakash Kansal[3] and Tareq Al-Ahdal[4]*

[1]Department of Community Medicine, ESIC Medical College and Hospital, Hyderabad, India, [2]Department of Community Medicine & School of Public Health, PGIMER, Chandigarh, India, [3]Global Health, Becton Dickinson, New Delhi, India, [4]Institute of Global Health (HIGH), Heidelberg University, Heidelberg, Germany

Background: Due to the COVID-19 pandemic, physical meetings and continuing medical education (CMEs) are being conducted in virtual mode. Digital sobriety has been advocated as a strategy for controlling the environmental emission from online events. The present study was undertaken to assess the impact of virtual CMEs on the environment and the participants' perception, knowledge, attitude, and practices of digital sobriety during the CMEs.

Methods: A retrospective cross-sectional Google form-based online study was conducted among the 1,311 registrants of 23 virtual CMEs hosted in India. A pre-tested English questionnaire was used to collect the data. The potential carbon footprint of the significant physical CME activities and the carbon emission (CE) of the virtual CMEs were estimated. Among the registrants contacted, 251 consented and participated in the study.

Results: The CE of the virtual CMEs was 0.787 metric tons of carbon dioxide equivalent (MT CO_2 Eq). If the CMEs were conducted physically, the potential CE was estimated to be 290.094 MT CO_2 Eq. The awareness rate of digital sobriety was 35%. Most of the participants (58.7%) from the current study preferred the hybrid mode of CMEs.

Conclusions: Virtual, digitally sober CMEs have reduced the potential CE by 99.7% compared to physical CMEs in India. The awareness and knowledge about digital sobriety is low in India. Knowledge, networking, social interactions, and overall satisfaction were relatively lower in the virtual mode of CMEs than in the physical mode.

KEYWORDS

environment, carbon footprint, India, telemedicine, virtual education

Introduction

Climate change is real, and every sector needs to do its part to mitigate and prevent the phenomenon. The environment is an integral part of human health and it should be considered and protected in all health-related activities. Continued Medical Education (CME) is essential to medical education and practices. The regulatory and supervisory bodies for medicine require mandatory CME credit hours from physicians to renew their practice licenses (1). Owing to the COVID-19 pandemic, meetings and teachings are being conducted in virtual mode. Telemedicine has been explored extensively in all aspects of medicine. In this pandemic, CMEs are also being conducted in virtual mode as a form of telemedicine. The environmental impact of this switch is mainly positive (2, 3). However, the online events have certain ecological consequences as well. A sizable carbon emission is contributed by servers, data consumption, software, and network usage (4). Digital and information technologies are credited with 3.7% of all carbon emissions (CE) (5). A single email generates 4 g of CO_2 equivalent. Similarly, every digital activity, such as streaming a video, visiting a webpage, or downloading a file, has its own carbon emission. Hence, strategies must be adopted to reduce carbon emission from virtual events. Digital sobriety has been advocated as a strategy for controlling the environmental emission from online events and enhance sustainable consumption of digital technology. Digital sobriety mainly consists of "buying the least powerful equipment possible, changing them the least often possible, and reducing unnecessary energy-intensive uses" (5). Institutions and individuals can adopt the digital sobriety strategies. Although the existing literature has quantified the emission from virtual events (6), including digitally sober scenarios (4, 7), they did not incorporate the duration spent in the virtual devises and mean years of usage of the devices, which are essential to improve the accuracy of the CE estimate. Also, no studies on the awareness and practice of digitally sober measures among attendees of virtual event could be found. Additionally, the impact of such a virtual switch of the CMEs on other essential domains of learners, such as knowledge, attitude, social relationships, and environmental effects from the delegates' perspective must also be studied in Indian settings. Therefore, the current study was conducted to assess the impact of virtual CMEs on the environment and participants' perception, knowledge, attitude and practices of digital sobriety in India, 2021.

Materials and methods

Study design

A Retrospective cross-sectional Google form-based online study.

Study population

Registrants of the Virtual Preconference CMEs conducted during the 48th "Annual Conference of the Indian Association of Preventive and Social Medicine (IAPSMCON 2021)"-—1,311. Registrants who did not give their consent were excluded.

Study settings

The IAPSMCON 2021 was held from 19th to 21st March 2021, which was the first in its series to be held virtually, due to the COVID-19 scenario. The Department of Community Medicine and School of Public Health, Postgraduate Institute of Medical Education and Research (PGIMER) at Chandigarh, India, organized the conference. There were 2,046 registrants for the conference. The most recent annual conference of the association (IAPSMCON 2023) was conducted offline with 1,300 participants. A series of 23 CMEs was conducted before the conference from 7th to 18th March 2021 by the organizers of the IAPSMCON 2021. Due to the COVID-19 situation, all CMEs were hosted in virtual mode by the Institute located in Chandigarh. There were 1,311 participants registered for the CMEs. The CMEs were conducted virtually through Zoom meetings. The registered participants were mailed the Zoom meeting code and password to attend the CME by the respective convener of the CME. The duration of the CMEs ranged from 2 to 11 hours.

Sample size and sampling technique

A complete enumeration of all registered participants was done-—1,311.

Data collection

The email IDs of the CME registrants were obtained from the IAPSMCON 2021 preconference CME database. A pre-tested, structured English questionnaire was sent as a Google form to the participants after all the CMEs were over. A maximum of three reminders were sent to registrants. For the percentage of delegates who would have attended the physical conference, the potential carbon footprint of the major physical conference activities, such as travel, lodging, meals, and certificates, was computed by extrapolating the responses given by the study participants. Similarly, the CE of the virtual CMEs was estimated.

Estimation of the CEs: Physical mode

The potential CE from the travel-related activities of the CME participants was estimated based on the mode of travel, which the probable attendants would have preferred to reach the CME venue, had it been in physical mode. The potential distance traveled (distance from the state capital of the participants to Chandigarh) (8, 9), and the CE per kilometer for each mode of travel (air, rail, and road) were used to calculate the CE for the transport activities (10–12). Based on an online tool (13), the potential CE from the accommodation of the CME participants and speakers and the CME halls were estimated. Three meals and two snack course was formulated, and the CE was estimated by tool which is available online (My Emissions) (14).

Estimation of the CEs: Virtual mode

The CE of the virtual platform, Zoom (https://zoom.us/), used to conduct the CMEs was assessed based on the number of users, usage hours and server usage.

The CE of the server were estimated by [1] (6):

$$E_e^* S^* Ws * H_c \quad (1)$$

Where Ee denotes the electricity emissions (kg CO_2-eq/kWh), S denotes number of servers (which was taken as 1), Ws represents the server's power rating (kW/server), and Hc is the total time for which the CMEs happened. CE from other virtual resources such as emails sent (15), webpages loaded (16), and devise usage to attend the CMEs (6), by the participants were also estimated.

The detailed methodology applied for estimating the CEs of the virtual and potential physical CMEs is mentioned in Supplementary material 1. The frequency of the potential carbon emission saved was calculated for each activity, and proportions were calculated to assess the contribution from each activity to total emissions.

A pre-tested, semi-structured questionnaire was applied to determine the knowledge, attitude and practices of digital sobriety among the participants. The items in the questionnaire assessed their awareness of the concept, activities which lead to carbon emission, their perception toward environmental protection by the virtual meeting, and their actual conduct and activities in the virtual systems during the CMEs.

Data analysis

MS Excel and SPSS v20 were used for data collation and analysis. In both the physical and online versions of the conferences, the potential CE of different activities was estimated. The total CE between the two versions of the conference was compared. The respondents' knowledge, perception and satisfaction levels from the virtual CME were expressed in proportions. A score was formulated to assess awareness and practice of digital sobriety. Continuous variables were assessed for normality (Kolmogorov-Smirnov test). Chi-square and Fisher's exact test were applied for testing the significance between categorical variables. Age, Gender, official designation of the participant, experience duration, duration of CME attended were the variables considered in the univariate model. The Mann-Whitney test was applied to assess the significance in the difference in continuous data between the respondents who were aware and not aware of digital sobriety. A multivariate analysis by multiple logistic regression was planned by including the variables which had a $p < 0.1$ in the univariate analysis.

Ethics

Ethical approval was taken from the Institutional Ethics Committee, PGIMER, Chandigarh. Since the study was conducted through google forms, virtual informed consent was obtained from the participants before starting the questionnaire providing all relevant information. All data collected was kept confidential and secure.

Results

Among the contacted registrants, 251 consented and completed the study (response rate: 19%). The median age of the participants was 29 years and the majority were females (63.7%) and junior residents (55%). Among the respondents, the majority (87.3%) responded that they would have attended the CMEs if it had happened in person mode.

TABLE 1 Socio-demographic characteristics of the respondents ($N = 251$).

Variable	Frequency	Percentage
Age median (IQR)	29 (27, 36) years	
Gender		
Male	90	35.9
Female	160	63.7
Prefer not to say	1	0.4
Designation		
Junior resident	138	55
Senior resident	19	7.6
Public health professional	24	9.6
PhD/Researcher	15	6.0
Faculty	46	18.3
Others	9	3.6
Years of work in the field Median (IQR)	2 (1.5, 5) years	
Would have attended physical CME		
Yes	209	87.3
No	42	16.7
Preferred mode of transport for physical CME ($N = 209$)		
Airways	103	49.3
Railways	62	29.7
Roadways	44	21.1
Preferred mode of the CME		
Physical	54	26.2
Virtual	24	11.7
Hybrid	121	58.7
Anything (no preference)	7	3.4
Attended CMEs during IAPSMCON 2021		
Yes	206	82.1
No	45	17.9
Total attended CME duration [median (IQR)]	4 (3, 5) hours	

TABLE 2 Carbon emission under various aspects during the virtual CMEs.

Emission heads	MT CO_2 Eq
Video streaming	0.592
Emails	0.015
E certificates	0.003
Website page views	0.012
Device usage	0.163
Zoom server usage	0.002
Total	**0.787**
Per capita emission	**0.001**

TABLE 3 Potential CE under various aspects during the physical CMEs.

Emission heads	Physical mode (CO_2 Eq MT)
Transport	217.030
Accommodation	57.570
Certificates	0.007
Food	15.488
Total	290.095
Per capital emission	**0.254**

Among the respondents, 82.1% (206) participated in the CMEs for a total median duration of 4 hours. The socio-demographic characteristics of the respondents are enumerated in Table 1.

As per the responses given by the study participants, the carbon emission due to the virtual CMEs was evaluated to be 0.787 metric tons carbon dioxide equivalent (MT CO_2 Eq) (Supplementary material 2). During the CMEs, most of the CE was from streaming the CME in the Zoom platform (75.2%), followed by device usage (20.7%) (Table 2).

Among the respondents, 87% committed that they would have attended the CMEs if it had been in physical mode. The potential CE of the probable 1,141 attendees (87% of the registrants), if the CMEs were held physically, was estimated to be 290.094 MT CO_2 Eq (Table 3; Supplementary material 3, 4). The potential per capita emission of the physical CMEs was 0.254 MT CO_2 Eq. The transportation activity that the delegates would have engaged in to attend the CMEs would have produced the majority of the potential CE from the physical-mode CMEs (74.8%). This was followed by accommodation (19.8%) and food (5.3%). Overall, the CE prevented in the CMEs by choosing the online mode was 289.308 MT CO_2 Eq (99.7%).

Among the CME attendees in our study (206), the awareness rate of "digital sobriety" was 35% (72). Majority of the attendees who responded (59.7%) did not know that the most commonly done day to day digital activities such as sending an email, watching a video, downloading a PDF file, opening a web page, sending a video through internet emits carbon (Table 4).

TABLE 4 Knowledge, attitude and practices of digital sobriety among the participants ($N = 206$).

Variables	Frequency	Percentage
Knowledge		
Aware of the term "digital sobriety"		
Yes	72	35.0
No	134	65.0
Digital activities that cause carbon emission		
Sending an email	23	12.1
Watching a 10 mins video in HD	60	29.1
Doing a google search	26	12.6
Opening a web page	22	10.7
Sending video file through internet	37	18
Downloading a PDF file	20	9.7
None of the above	123	59.7
Attitude		
Do not cause ANY adverse environment impact when they attend the virtual CMEs		
Strongly disagree	64	31.1
Disagree	52	25.2
Neither disagree nor agree	47	22.8
Agree	24	11.7
Strongly agree	19	9.2
Virtual mode of CMEs reduces the adverse environmental impact caused by the physical mode		
Strongly disagree	45	21.8
Disagree	55	26.7
Neither disagree nor agree	50	24.3
Agree	31	15.0
Strongly agree	25	12.1
Attending virtual CMEs is a contribution to environment protection		
Yes	188	91.3
No	18	8.7
Practices		
Self-video during virtual CME		
Video camera was switched off all the time	104	50.5
Video camera was switched OFF most the time (more than 50% of the meeting duration)	75	36.4
Video camera was switched on all the time	10	4.9
Video camera was switched ON most of the time (more than 50% of the meeting duration)	17	8.3
Time of switching on the camera during the CMEs		
All the time	7	3.4
Most of the time (>50% of the duration)	15	7.3
Never during the meeting	85	41.3
When they need to speak or ask question	99	48.1

TABLE 5 Association between the awareness of digital sobriety and the socio-demographic, KAP domains of environmental aspects of virtual CME.

Variable	Aware about the term "Digital Sobriety"				*p* value
	Yes		No		
	n	%	*n*	%	
Gender					
Male	26	36.6	45	63.4	0.744[a]
Female	46	34.3	88	65.7	
Designation					
Junior resident	39	34.2	75	65.8	0.932[b]
Senior resident	7	43.8	9	56.3	
Public health professional	7	41.2	10	58.8	
PhD/Researcher	4	30.8	9	69.2	
Faculty	14	34.1	27	65.9	
Others	1	20	4	80	
Age, median (IQR)	29.5 (28, 35.8)	–	29 (27, 35)	–	0.632[c]
Years of work in the field, median (IQR)	8 (4, 12)	–	8 (4, 16)	–	0.315[c]
Total duration of CME attended, median (IQR)	4 (3, 4)	–	4 (3, 6)	–	0.235[c]
Total KAP score	9 (7, 11)	–	8 (6, 11)	–	0.224[c]

[a]Chi-square test.
[b]Fishers exact test.
[c]Mann-Whitney Test.

Most of the participants had a positive attitude towards virtual CMEs that they contribute to environmental protection by attending such virtual CMEs (91.3%).

Regarding the practices of digital sobriety acts, most had switched off their video cameras at all (50.5%) or most of the time (36.4%) and turned them on only when they needed to speak or ask a question (48.1%).

Among the participants in our study, the awareness rate of digital sobriety was 35%. No significant association was found between the respondents' socio-demographic factors and their awareness of digital sobriety. Similarly, the two groups' total knowledge attitude and practice scores estimated toward the environmental aspects of the virtual CME were also similar (Table 5).

The majority of CME attendees expressed that knowledge acquired (49.5%), interactive sessions (59.2%), networking achieved with peers (72.8%), social relationships developed (82%), the ambience (62.1%) and overall satisfaction (54.9%) from the virtual mode of the CMEs have been lower in comparison with that of the physical mode (Table 6).

Discussion

Moving academic meetings and conferences to an online platform have been proposed as an effective strategy to reduce the environmental impact of such sessions (20, 21). In the present study, the estimated per capita CE for attending virtual CMEs was 1 Kg of CO_2 Eq (0.001 MT CO_2 Eq), while the physical mode of CMEs would have caused a potential per capita CE of 254 Kg of CO_2 Eq. In comparison, the CE per capita of the people living in India is 2.7 MT CO_2 Eq (22). Potential CE saved during the CMEs included in the present study by adopting the virtual mode was 289.308 MT CO_2 Eq (99.7%). This is significant considering the reports that put the estimate of CO_2 emission by the event industry across the world to be around 10% of global CO_2 emission (23).

Studies have reported a similar reduction in CE by adopting the virtual mode of academic events over the physical mode. A reduction in CE by 66–200 times has been reported (6, 24). A comparison between the virtual meeting of "American Association for Pediatric Ophthalmology and Strabismus (AAPOS)" in 2021 and the physical version of the meeting which happened in 2022 revealed a reduction of CE between 880 and 1,282 MTCO_2 due to the virtual version (25). Travel component in physical conferences and meetings is considered a major contributor to carbon emission (26). The potential CE of transport involved in attending the CMEs and returning has been estimated to be the single most important factor in the overall potential of CE. This is in line with previous literature, which also found transport to be the predominant factor (21, 27, 28). Travel-related emissions incurred to present a paper at conferences were pegged at 0.8 MT CO_2 Eq, worldwide (29).

Although there was a huge reduction in CE owing to the virtual mode of CMEs, the present study delved micro level to assess the digital sobriety among the attendee. The present study found a 35% awareness rate about "digital sobriety" among the attendees. No significant association was found between the socio-demographic factors and their awareness of digital sobriety.

Digital sobriety assumes significance in the context that the carbon footprint attributed to digital activities increases at a rate of 8% annually (17). Most participants had a positive attitude toward

virtual CMEs that they contribute to environmental protection by attending such virtual CMEs (91.3%). At the individual level, most of the study participants had switched off their video cameras all (50.5%) or most of the time (36.4%) and turned them on only when they needed to speak or ask a question (48.1%). This assumes importance, since keeping the self-videos switched off by the attendees during the virtual events reduced carbon emissions by about 96% compared to keeping the video switched on all the time (6). Though not all adopted this measure of digital sobriety, the majority reported following it, making the CMEs a digitally sober event. This practice affected the CE contributed by the virtual CME.

Regarding knowledge about digital sobriety, the majority of study participants (59.7%) did not know that the most commonly done day-to-day digital activities, such as sending an email, watching a video, downloading a PDF file, opening a web page, sending a video file through the internet, emits carbon. This is a point of concern, as it denotes inadequate awareness of the environmental impact of digital activities, even among the educated lot in the health sector. Previous studies also showed a lack of awareness among users regarding the environmental impact of the internet and digital products (30, 31). Gnanasekaran et al., in their study, reported poor awareness of the digital carbon footprint of online applications and services used by people who are avid users of such services (31). The role of the internet in CE seems to be underestimated by the users, while estimates report that the internet consumes 10% of the world's electricity (32). The potential reasons behind the underestimate could be a lack of knowledge as per the present study and a previous study (30). Other possible reasons might be accepting internet pollution as a side effect of other benefits from it and unwillingness to act (30). The facilitators and barriers for adopting and practicing eco-friendly online practices at the individual level among participants in our study must be explored through a qualitative study. This is essential since the proportionate share of the internet in pollution has been increasing rapidly over the past decade. Digital devices and support systems emit 3.7% of total greenhouse gas emissions, which is on the rise (32).

The majority of CME attendees expressed that knowledge acquired (49.5%), interactive sessions (59.2%), networking achieved with peers (72.8%), social relationships developed (82%), the ambience (62.1%) and overall satisfaction (54.9%) from the virtual mode of the CMEs have been lower in comparison with that of the physical mode. This indicates the need to understand the determinants for such a relatively lower satisfaction in the virtual mode of the event than in the physical mode, among the study participants. Of their Korean participants in a virtual conference, Kim et al. reported an overall median satisfaction and social exchanges score of 3 and 2.7, respectively, on a 5-point Likert scale (33). Though the overall perception from the Korean study was positive, the methodology differed from the present study.

Although the majority of participants from the current study preferred the hybrid mode of CMEs (physical and virtual modes) followed by the physical mode (26.2%), Kim et al. reported that 50% of their participants preferred the virtual mode of conferences, while 33% had a preference for the conventional physical mode (33).

TABLE 6 Opinion toward the virtual CME in comparison to the physical CMEs among the participants.

Knowledge acquired in virtual CME	Frequency	Percentage
Less than that of physical mode	102	49.5
Same as that of physical mode	65	31.6
More than that of physical mode	39	18.9
Interactive sessions during the CME		
Less than that of physical mode	122	59.2
Same as that of physical mode	43	20.9
More than that of physical mode	41	19.9
Networking achieved with peers		
Less than that of physical mode	150	72.8
Same as that of physical mode	24	11.7
More than that of physical mode	32	15.5
Social relationships developed/maintained		
Less than that of physical mode	169	82.0
Same as that of physical mode	19	9.2
More than that of physical mode	18	8.7
Ambience (atmosphere of the CME in the virtual platform)		
Less than that of physical mode	128	62.1
Same as that of physical mode	43	20.9
More than that of physical mode	35	17.0
Overall satisfaction level with the virtual CME		
Less than that of physical mode	113	54.9
Same as that of physical mode	61	29.6
More than that of physical mode	32	15.5

Lower satisfaction with social relationships and exchanges has been reported in our study, which is in line with previous studies (33, 34). A blended or hybrid mode of academic meetings is suggested to address this limitation of the total virtual mode (25, 35, 36). Since most of the present study participants also preferred a hybrid mode for the CMEs, this can be implemented in our settings in the near future to study the impact on the social relationships and interactions of the participants. Multiple formats within the blended model have been proposed that can be tailored and tested in current settings (18, 19).

According to our literature search, this is the first study from India to report on the awareness and practices of digital sobriety among the attendees of virtual events. The accuracy of the CE of the virtual event was improved by including the details on the video mode, type of device used to attend the event, years of durability and daily hours of usage of the device. However, our findings should be interpreted cautiously due to the following limitations. A low response rate of 19% was found in the study, which could have led to selection bias. Participants attended the CMEs under a single institute and domain (public health), thus limiting its external validity. Potential determinants of the lack of awareness

of the environmental impact of the internet and digital activities were not elicited. Future studies should be conducted to explore the determinants of low awareness and knowledge of digital sobriety.

Conclusions

Virtual, digitally sober CMEs have reduced the potential CE by 99.7% compared to physical CMEs in India. The awareness and knowledge about digital sobriety may be low in India. Knowledge, networking, social interactions, and overall satisfaction were relatively lower in the virtual mode of CMEs than in the physical mode. Participants prefer the hybrid mode of CMEs over exclusive physical or virtual modes. Institutions and individuals must be encouraged to adopt digitally sober online and virtual world strategies, thus promoting sustainable consumption in virtual events.

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 human participants were reviewed and approved by Institute Ethics Committee, PGIMER, Chandigarh, India. The patients/participants provided their Virtual informed consent to participate in this study.

Author contributions

Conceptualization: AG and KG. Methodology: TA-A, AG, KG, BP, AS, and OK. Formal analysis and investigation: AG, KG, and BP. Writing—original draft preparation: AG. Writing—review and editing: TA-A, KG, BP, AS, and OK. Supervision: KG. All authors read and approved the final manuscript.

Conflict of interest

OK was employed by Becton Dickinson.

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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1118685/full#supplementary-material

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Christiane Stock,
Charité Medical University of Berlin, Germany

REVIEWED BY
Souheila AliHassan,
United Arab Emirates University, United Arab Emirates
Peijing Yan,
Department of Epidemiology and Health Statistics, Sichuan University, China
Sidra Abbas,
COMSATS University Islamabad, Sahiwal Campus, Pakistan
Mingquan Lin,
Cornell University, United States

*CORRESPONDENCE
Yaolong Chen
✉ chenyaolong@lzu.edu.cn
Ruitai Shao
✉ shaoruitai@sph.pumc.edu.cn

†These authors have contributed equally to this work

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Characteristics of the sources, evaluation, and grading of the certainty of evidence in systematic reviews in public health: A methodological study

Yangqin Xun[1†], Qiangqiang Guo[2†], Mengjuan Ren[2], Yunlan Liu[2], Yajia Sun[2], Shouyuan Wu[2], Hui Lan[2], Juanjuan Zhang[2], Hui Liu[2], Jianjian Wang[3], Qianling Shi[4], Qi Wang[5,6], Ping Wang[1], Yaolong Chen[1,2,7,8,9*], Ruitai Shao[10,11*] and Dong Roman Xu[12]

[1]Evidence-Based Medicine Center, School of Basic Medical Sciences, Lanzhou University, Lanzhou, China, [2]School of Public Health, Lanzhou University, Lanzhou, China, [3]West China School of Public Health and West China Fourth Hospital, Sichuan University, Chengdu, China, [4]The First School of Clinical Medicine, Lanzhou University, Lanzhou, China, [5]Department of Health Research Methods, Evidence and Impact, Faculty of Health Sciences, McMaster University, Hamilton, ON, Canada, [6]McMaster Health Forum, McMaster University, Hamilton, ON, Canada, [7]Research Unit of Evidence-Based Evaluation and Guidelines, Chinese Academy of Medical Sciences (2021RU017), School of Basic Medical Sciences, Lanzhou University, Lanzhou, China, [8]Lanzhou University, An Affiliate of the Cochrane China Network, Lanzhou, China, [9]World Health Organization (WHO) Collaborating Centre for Guideline Implementation and Knowledge Translation, Lanzhou, China, [10]School of Population Medicine and Public Health, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China, [11]Department of Non-communicable Diseases, World Health Organization (WHO), Geneva, Switzerland, [12]SMU Institute for Global Health (SIGHT), School of Health Management and Dermatology Hospital, Southern Medical University (SMU), Guangzhou, China

Objectives: To systematically explore how the sources of evidence, types of primary studies, and tools used to assess the quality of the primary studies vary across systematic reviews (SRs) in public health.

Methods: We conducted a methodological survey of SRs in public health by searching the of literature in selected journals from electronic bibliographic databases. We selected a 10% random sample of the SRs that met the explicit inclusion criteria. Two researchers independently extracted data for analysis.

Results: We selected 301 SRs for analysis: 94 (31.2%) of these were pre-registered, and 211 (70.1%) declared to have followed published reporting standard. All SRs searched for evidence in electronic bibliographic databases, and more than half (n = 180, 60.0%) searched also the references of the included studies. The common types of primary studies included in the SRs were primarily cross-sectional studies (n = 132, 43.8%), cohort studies (n = 126, 41.9%), randomized controlled trials (RCTs, n = 89, 29.6%), quasi-experimental studies (n = 83, 27.6%), case-control studies (n = 58, 19.3%) qualitative studies (n = 38, 12.6%) and mixed-methods studies (n = 32, 10.6%). The most frequently used quality assessment tools were the Newcastle-Ottawa Scale (used for 50.0% of cohort studies and 55.6% of case-control studies), Cochrane Collaboration's Risk of Bias tool (50.7% of RCTs) and Critical Appraisal Skills Program (38.5% of qualitative studies). Only 20 (6.6%) of the SRs assessed the certainty of the body of evidence, of which 19 (95.0%) used the GRADE approach. More than 65% of the evidence in the SRs using GRADE was of low or very low certainty.

Conclusions: SRs should always assess the quality both at the individual study level and the body of evidence for outcomes, which will benefit patients, health care practitioners, and policymakers.

KEYWORDS

public health, evidence, quality assessment, certainty of evidence, systematic reviews, methodological survey

1. Introduction

The term *Evidence-Based Medicine* (EBM) was first used in the scientific literature in 1991 (1). After 30 years, the concepts and methods of EBM have gradually penetrated into other research fields and subjects, including public health. Evidence-Based Public Health (EBPH) aims to integrate science-based interventions with the actual national and regional needs and priorities to improve the health of the population (2–4).

Public health professionals should always review the existing scientific evidence when planning and implementing projects, developing policies, and assessing progress (5). EBPH involves the systematic and comprehensive identification and evaluation of the best available evidence, to provide an explicit and valid scientific basis for public health policy making. However, studies have shown that the evidence in the area of public health is often insufficient to support decision-making, and the methodological approaches and quality of the evidence vary widely (6–8). Effective decision-making in public health requires high-quality evidence (9). High risk of bias in research evidence reduces the overall certainty of the body of evidence, which can lead to tentative or conditional recommendations, and potentially even to decisions that are harmful to patients and populations. It is therefore important to assess both the risk of bias in individual studies and the overall quality (or certainty) of the body of the evidence used for decision-making.

Systematic reviews (SRs) are now widely used to inform public health policies (10) and decisions (11). Evidence retrieval, evaluation, and quality assessment are key steps when conducting SRs. Researchers have explored how these steps were completed in SRs on certain topics, for instance, biomedical investigations (12), preclinical studies (13) and nutritional epidemiologic studies (14, 15). Many problems and limitations were found in these areas.

Given the specific and complex nature of public health as a field of research, a methodological investigation of systematic evaluation of evidence in public health research is needed. To date, no study has however assessed how these essential steps of evidence collection and synthesis are executed in SRs on public health topics. Therefore, this study aims to investigate how the sources, types and quality assessment methods of evidence vary across SRs in public health. The results of this study will provide valuable insights for systematic reviewers, journal editors, primary researchers, public health professionals, and policy-makers on the identification and assessment methods of primary studies and the distribution of different study types among them and how systematic review teams in the field of public health should improve their work.

Abbreviations: AMSTAR, A MeaSurement Tool to Assess systematic Reviews; CASP, Critical Appraisal Skills Program; EBPH, Evidence-Based Public Health; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; IQR, interquartile range; NOS, Newcastle-Ottawa Scale; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analysis; RCT, randomized controlled trial; ROB, Cochrane Collaboration's Risk of Bias; SR, Systematic review.

2. Materials and methods

2.1. Study design

We performed a methodological survey of SRs in public health, randomly sampled from publications identified through a comprehensive literature review.

2.2. Study selection

We used the filter category "Public, Environmental & Occupational Health" in the "Journal Citation Reports" module of the Web of Science (16) to limit the number of journals. We also ran a supplementary manual search of ten English medical journals that had the terms "evidence-based" and "systematic review" in their title. Then, limited to the journals mentioned above, the search strategy using the string "meta-analysis" OR "systematic review" OR "systematic assessment" OR "integrative review" OR "research synthesis" OR "research integration" in the title was constructed. We applied this search strategy from January 2018 to April 2021 to Medline (*via* PubMed). We present the details of the search strategy in Appendix 1. Two reviewers conducted the electronic database search independently and discussed the results until a consensus was reached.

2.3. Eligibility criteria

2.3.1. Inclusion criteria

We included SRs in public health that met the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) definition of a systematic review, that is, articles that explicitly state the methods of study identification (i.e., a search strategy), study selection (e.g., eligibility criteria and selection process), and synthesis (or other types of summary) (17). Public health is defined as the promotion and protection health and

wellbeing, prevention of illness and prolongation of life through organized societal efforts, and it includes three key domains: health improvement, improving services, and health protection (18). We included only published SRs written in English.

2.3.2. Exclusion criteria

We excluded the following types of articles: systematic review of guidelines; overviews of reviews (or umbrella reviews); scoping reviews; methodological studies that included a systematic search for studies to evaluate some aspect of conduct or reporting; and protocols or summaries of SRs. We excluded articles for which the full text was not accessible. We also excluded commentaries, editorials, letters, summaries, conference papers and abstracts.

2.4. Literature screening and data extraction

Literature screening and data extraction were conducted by two researchers (eight researchers divided into four pairs) independently. Disagreements were resolved by discussion or consultation with a third researcher until consensus was reached. The titles and abstracts were first screened and obviously irrelevant publications were excluded. Then the full texts of the potentially eligible articles were read to determine if the article met the inclusion criteria. Finally, the included SRs were randomly ordered and a 10% sample was randomly selected using the RAND function in Microsoft Excel 2010 (Redmond, WA, USA). In this article, we present the flow diagram of the literature search, inclusion and exclusion criteria using the PRISMA 2020 27-item checklist (19).

Data were extracted from the final study sample using a standard data extraction form by two researchers independently. The data extraction form was developed through two rounds of pre-test followed by and discussions. The form included basic information (year of publication, journal of publication, country or region of the first author, number of authors, platform of registration, reporting statement, and funding); the name and number of included databases, websites, registration platforms and other supplementary search sources; the types and numbers of studies included in the SR (the study type is directly extracted according to the type reported in the SR); quality assessment tools used for included studies included in the SR; and the approach used to assess the quality (or certainty) of the body of evidence.

2.5. Statistical analysis

The tools used for quality assessment of the individual studies in each SR were identified from the full texts of each study report. The Newcastle-Ottawa Scale (NOS) tool is commonly used for cohort studies and case-control studies, the Cochrane Collaboration's Risk of Bias (ROB) tool for randomized controlled trials (RCTs), and the Critical Appraisal Skills Program (CASP) tool for qualitative studies. In these all three tools, each item is assigned a value 1 if the answer to the corresponding question was "yes" or "partial yes", and 0 if the answer was "no" or "cannot tell". Specially, the "Comparability" item in NOS may get a maximum value of 2, as it assesses the study controls for the most important factor and a second important factor. The risk of bias is defined as low if the total score for each primary study is $\geq$70% of the possible maximum score; high if the total score was $\leq$35% of the possible maximum score; and moderate if the total score was between 35 and 70% of the possible maximum score. We calculated on the item scores directly from the assessment of the authors of the include reviews, and then evaluated the overall methodological quality of the primary studies as described above.

We performed a descriptive analysis of the basic characteristics and reporting features of the included SRs. Continuous variables were expressed as medians and interquartile ranges (IQR), and categorical variables frequencies and percentages. We performed all statistical analyses using IBM SPSS 26.0 (Armonk, NY, USA).

3. Results

The initial search yielded 7,320 articles. After screening titles, abstracts, 3,010 articles were retrieved, and 10% of the retrieved articles ($n = 301$) were randomly selected for inclusion (Figure 1).

3.1. Characteristics of the included studies

Characteristics of the included studies are shown in Table 1. The number of published SRs in public health increased over time. The first authors came from a total of 42 countries. The median number of authors per SR was five (IQR 4–6), and four (1.3%) SRs were conducted by one author. The median number of included studies was 19 (IQR 12–35), and only one (0.3%) SR identified no eligible studies. The SRs were published in 116 different journals among which the *International Journal of Environmental Research and Public Health* had the highest number of publications (n = 5,217.3%). Only one-third of the SRs were registered (n = 94, 31.2%). However, more than half of the SRs declared to have followed reporting guidances (n = 211, 70.1%). Almost three quarters of the SRs ($n = 221$, 73.4%) evaluated the methodological quality of the primary studies included in the SRs, however, only 6.6% (n = 20) of the SRs assessed the certainty of the body of evidence. Half of the SRs (n = 146, 48.5%) reported the funding sources for the SR. For about one fourth of the SRs (n = 81, 27.0%) were classified as etiology, for 69 (23.0%) as distribution, for 46 (15.3%) as therapeutic, for 40 (13.3%) as prevention, for eight (2.6%) as screening, for four (1.3%) as diagnosis or prognosis, and for 53 (17.5%) as other.

3.2. Sources of evidence

All SRs included in this study searched electronic bibliographic databases for evidence (Table 2). A total of 173 different databases were searched, the total frequency was 1,331, and the median number of databases retrieved per SR was four (IQR, 3–5). Some database weresearched through various platforms varied for some of the databases. For example, Medline was accessed through EBSCO, Web of Science, Ovid, and the

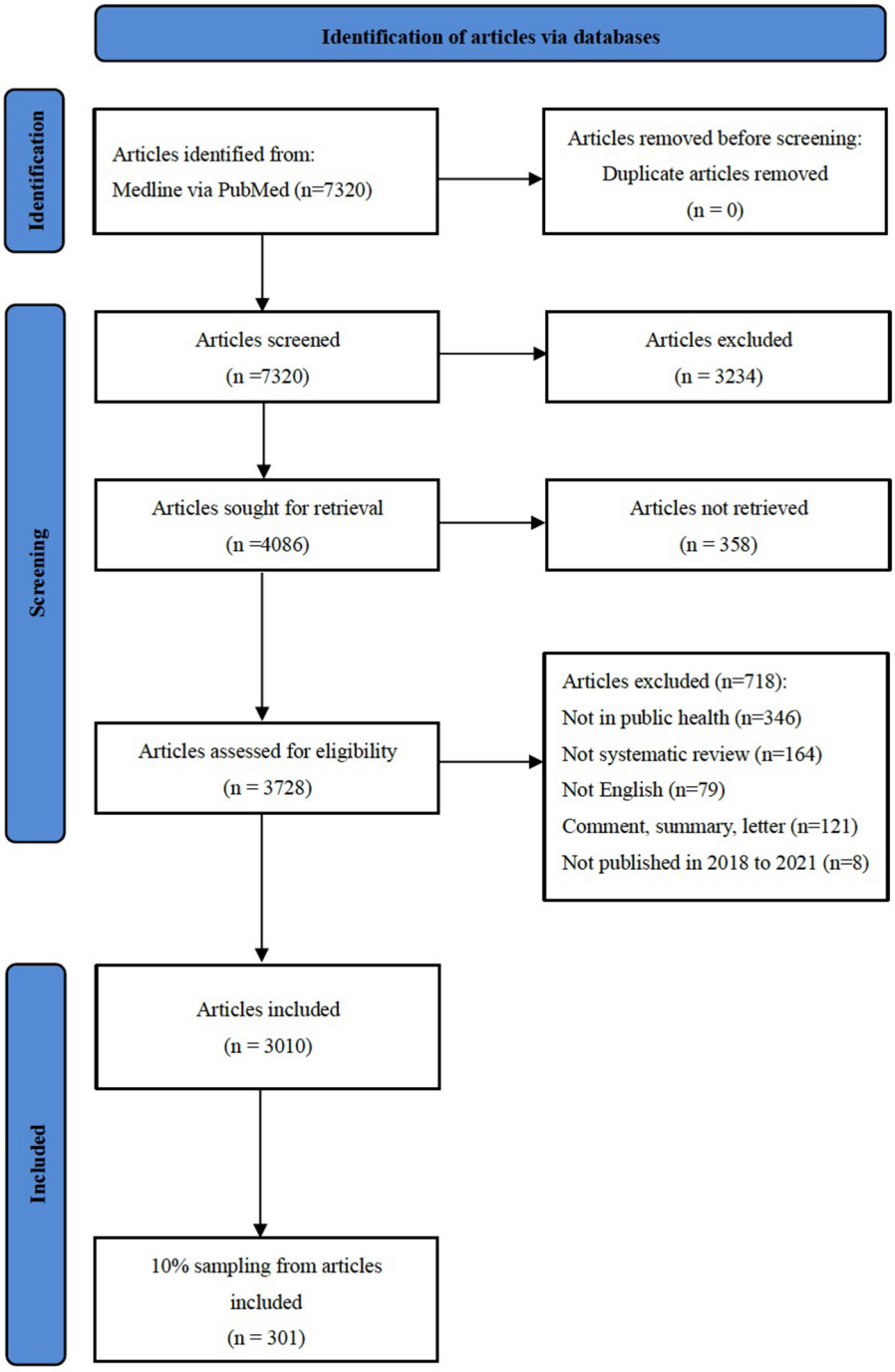

FIGURE 1
Flow diagram of the literature search.

Virtual Health Library. Sixty percent of the SRs (n = 180) searched the references of included studies in addition to electronic databases. A total of 62 websites [the total frequency was 80, and the most commonly searched for websites was the World Health Organization (n = 5)] and 8 registration platforms [the total frequency was 55, and the most commonly searched was the Cochrane Central Register of Controlled Trials (n = 28)].

3.3. Types of primary studies of SRs

The most common types of primary studies included in the SRs were cross-sectional studies (n = 132, 43.8%); cohort studies (n = 126, 41.9%); RCTs (n = 89, 29.6%); quasi-experimental studies including non-randomized trials and before and after studies (n = 83, 27.6%); and case-control studies including nested case-control studies, case-cohort studies and case-crossover studies (n = 58,

TABLE 1 Characteristics of the included systematic reviews ($n = 301$).

Variables	*n* (%)
Year of publication	
2018	60 (20.0)
2019	87 (28.9)
2020	119 (39.5)
2021	35 (11.6)
Number of authors (Median, IQR)	5 (4–6)
Country of the first author	
United States of America	56 (18.6)
United Kingdom	35 (11.6)
Australia	30 (10.0)
China	30 (10.0)
Iran	14 (4.7)
Canada	13 (4.3)
Spain	13 (4.3)
Germany	12 (4.0)
Ethiopia	9 (3.0)
Italy	9 (3.0)
Korea	9 (3.0)
Netherlands	8 (2.6)
Brazil	6 (2.0)
Switzerland	6 (2.0)
Japan	5 (1.7)
Others[a]	46 (15.2)
Protocol registration	
PROSPERO	92 (30.6)
Open Science Framework	2 (0.6)
None	207 (68.8)
Reporting statements cited[b]	
PRISMA and its extensions	204 (67.8)
MOOSE	10 (3.3)
ENTREQ	2 (0.7)
Others[c]	3 (1.0)
No	90 (30.0)
Funding for the systematic review reported	
Yes	146 (48.5)
No	155 (51.5)
Methodological quality of the primary studies assessed	
Yes	221 (73.4)
No	80 (26.6)
Quality of the body of evidence assessed	
Yes	20 (6.6)
No	281 (93.4)
Type of the systematic review	
Etiology	81 (27.0)
Distribution	69 (23.0)
Therapeutic	46 (15.3)
Prevention	40 (13.3)
Screening	8 (2.6)
Diagnosis/Prognosis	4 (1.3)
Other	53 (17.5)
Systematic reviews of interventions	
Yes	86 (28.6)
No	215 (71.4)
Number of the included primary studies (Median, IQR)	19 (12–35)

[a]Others included France ($n = 4$), Greece ($n = 4$), Portugal ($n = 4$), Singapore ($n = 3$), Thailand ($n = 3$), Belgium ($n = 2$), Cameroon ($n = 2$), Finland ($n = 2$), Norway (n =2), South Africa ($n = 2$), United Arab Emirates ($n = 2$), Austria ($n = 1$), Bangladesh ($n = 1$), Chile ($n = 1$), Colombia ($n = 1$), Denmark ($n = 1$), Ireland ($n = 1$), Lebanon ($n = 1$), Malaysia ($n = 1$), New Zealand ($n = 1$), Nigeria ($n = 1$), Pakistan ($n = 1$), Philippines ($n = 1$), Serbia ($n = 1$), Slovenia ($n = 1$), Sweden ($n = 1$), Tanzania ($n = 1$).

[b]Some studies reported following two or more reporting statements.

[c]Others included the Center for Reviews and Dissemination, Method for the thematic synthesis of qualitative research in systematic reviews, ROSES (RepOrting Standards for Systematic Evidence Syntheses).

ENTREQ, Enhancing transparency in reporting the synthesis of qualitative research; IQR, interquartile range; MOOSE, Meta-analysis Of Observational Studies in Epidemiology; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

19.3%); qualitative studies ($n = 38$, 12.6%) and mixed-methods studies ($n = 32$, 10.6%). In addition, 73 of the SRs (24.2%) included other types of studies such as descriptive studies, observational studies, prospective studies, and retrospective studies. Details are shown in Figure 2.

3.4. Methodological quality assessment tools

Table 3 shows the main methodological quality assessment tools (The frequency of use was ≥2) used for different study types. The most frequently used tools were NOS (used for 50.0% of cohort studies and 55.6% of case-control studies), ROB (50.7% of RCTs) and CASP (38.5% of qualitative studies). The median score for cohort studies assessed with NOS was 7.0 (possible maximum score 9), indicating low risk of bias. "Comparability" and "Adequacy of follow up of cohorts" were the items least frequently assessed or reported (Appendix 2). The median score reported with the NOS for case-control studies was 7.0 (possible maximum score 9), also indicating low risk of bias. "Selection of Controls" and "Non-Response rate" were the item least frequently assessed or reported (Appendix 3). The median score for RCTs assessed with ROB was 4.0 (possible maximum score 7), meaning therisk of bias

TABLE 2 Sources of primary studies most frequently searched in the included systematic reviews ($n = 301$).

No.	Databases	*n* (%)
1	PubMed	181 (60.1)
2	Medline	161 (53.5)
3	Embase	159 (52.8)
4	Web of science	126 (41.9)
5	PsycInfo	94 (31.2)
6	CINAHL (Cumulative Index to Nursing and Allied Health Literature)	93 (30.9)
7	Scopus	77 (25.6)
8	Cochrane library	64 (21.3)
9	Science direct	22 (7.3)
10	CNKI (Chinese National Knowledge Infrastructure)	12 (4.0)
11	SPORTDiscus	12 (4.0)
12	ERIC (Educational Resources Information Center)	11 (3.6)
13	LILACS (Latin American and Caribbean Health Sciences Literature)	11 (3.6)
14	EBSCO	10 (3.3)
15	Global health	10 (3.3)
No.	Websites	n (%)
1	WHO (World Health Organization)	5 (1.7)
2	NICE (National Institute for Health and Care Excellence)	3 (1.0)
3	UNICEF (United Nations Children's Fund)	3 (1.0)
4	US-CDC (United States Centers for Disease Control and Prevention)	3 (1.0)
5	ECDC (European Center for Disease Prevention and Control)	2 (0.7)
6	ICRC (International Committee of the Red Cross)	2 (0.7)
7	IOM (International Organization of Migration)	2 (0.7)
8	IRC (International Rescue Committee)	2 (0.7)
9	MSF (Médecins Sans Frontières)	2 (0.7)
10	ReliefWeb	2 (0.7)
11	UNAIDS (Joint United Nations Programme on HIV/AIDS)	2 (0.7)
12	UNHCR (United Nations High Commissioner for Refugees)	2 (0.7)
No.	Registration platforms	*n* (%)
1	CENTRAL (Cochrane Central Register of Controlled Trials)	28 (9.3)
2	ClinicalTrials.gov	13 (4.3)
3	ICTRP (WHO International Clinical Trials Registry Platform)	8 (2.6)
4	Australian New Zealand Clinical Trials Registry	2 (0.7)
No.	Other sources	*n* (%)
1	Scanning the reference lists and other relevant review articles	180 (60.0)
2	Google Scholar	63 (20.9)
3	Google	15 (5.0)
4	Experts' consultation	12 (4.0)
5	Conference proceedings	11 (3.6)
6	Contact the authors	10 (3.3)
7	Specialist journals	7 (2.3)
8	Other handing searching methods	23 (7.6)

Some researchers regard PubMed as a database rather than a search platform. And we only extracted data that were reported in each SR.

was moderate. "Allocation concealment", "Blinding of participants and personnel" and "Blinding of outcome assessment" were the least frequently assessed or reported items (Appendix 4). The median score for qualitative studies assessed with CASP was 9.0, out of a possible maximum score of 10. It was at low risk of bias. "Personal biases" and "Ethical considerations" were the items least frequently assessed or reported (Appendix 5). Five SRs used reporting checklists or an evidence grading system to evaluate the methodological quality.

3.5. Grading of certainty of evidence

Only 6.6% of the SRs ($n = 20$) assessed the certainty of the body of evidence for selected outcomes. The vast majority of these ($n = 19$, 95.0%) used the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach, while one study used the Oxford Center for Evidence-based Medicine (OCEBM) system (Table 4). The SRs that used GRADE evaluated a total of 111 outcomes: the certainty of the evidence was assessed as high for 11 (9.9%), moderate for 27 (24.3%), low for 28 (25.3%), and very low for 45 (40.5%) (Table 4). It is important to note that when reporting results for the GRADE assessments, these assessments are made at the level of individual outcomes, and some included reviews maybe contribute more than one assessment to this data. Ten (11.6%) of the 86 SRs of interventionsgraded the certainty of evidence including a total of 78 outcomes. The certainty of the evidence was high in11 (14.1%), moderate for 23 (29.5%), low for 16 (20.5%) and very low for 28 (35.9%).

4. Discussion

4.1. Summary of main results

The main sources of evidence in a random sample of SRs in public health were electronic bibliographic databases. Other sources of evidence were used by <20% of the SRs. Cross-sectional studies represented more than a third of the primary studies included in the SRs, followed by cohort studies and RCTs. While

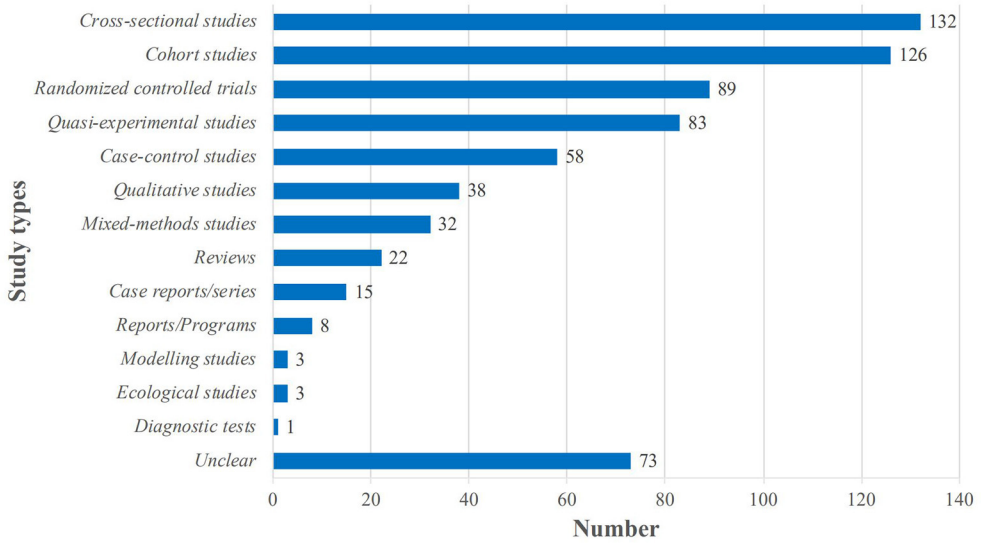

FIGURE 2
Distribution of the types of primary studies in the included systematic reviews ($n = 301$). Quasi-experimental studies including non-randomized trials and before and after studies; Case-control studies including nested case-control studies, case-cohort studies and case-crossover studies; "Unclear" means that it is not possible to identify the specific type of study, such as descriptions studies, observational studies, prospective studies, and retrospective studies and so on.

more than 70% of the SRs evaluated the quality of the included studies using a broad range of quality assessment tools, only 6% assessed the certainty of the body of evidence. Of SRs on interventions, 11% graded the certainty of evidence. More than three quarters of the evidence assessed by GRADE was found to be of low or very low certainty.

4.2. Sources of evidence

A well-conducted systematic analyzes all available evidence to answer a carefully formulated question. It employs an objective search of the literature, applies predetermined inclusion and exclusion criteria, and critically appraises what is found to be relevant. However, systematic reviews may differ in quality, and yield different answers to the same question. As a result, users of systematic reviews should be critical and look carefully at the methodological quality of the available reviews. AMSTAR (updated to AMSTAR 2 in 2017) has been proven to be a reliable and valid measurement tool for assessing the methodological quality of systematic reviews (20–22). Item 3 in AMSTAR and item 4 in AMSTAR 2 state that authors need to use a comprehensive literature search strategy specifically requiring that at least two bibliographic databases should be searched. Searches should be supplemented by checking published reviews, specialized registers, or contacting experts in the particular field of study, and by reviewing the reference lists of the identified studies. Sometimes it is necessary to search websites (e.g., government agencies, non-governmental organizations or health technology agencies), trial registries, conference abstracts, dissertations, and unpublished reports on personal websites (e.g., universities, ResearchGate). In addition, PRISMA-S, an extension to the PRISMA Statement for Reporting Literature Searches in Systematic Reviews, covers multiple aspects of the search process for systematic reviews and presents a 16-item checklist similar to the AMSTAR (23).

Our study found that the median number of databases searched for each SR was four. To gain a comprehensive collection of research evidence on public health topics, it is necessary to search extensively also beyond Medline, including topic-specific databases as appropriate (24, 25). Although many scholars consider Medline as the most essential source of medical literature (24, 26). It does not exhaustively cover all the evidence related to public health, particularly publications with a regional or local focus. Therefore, researchers are encouraged to consider topic-specific databases (27). Other important sources for evidence in public health include reports from research organizations, governments and public health agencies, which are often not published in peer-reviewed journals, and can only be found on the organization's website (28). However, our findings show that most of the SRs did not supplement the evidence through other sources. Researchers are therefore encouraged to consider additional sources to retrieve evidence, such as registration platforms, conference proceedings, or contacting authors of key publications.

4.3. Types of evidence and methodological quality assessment tools

SRs of public health literature encompass evidence from a wide range of study designs, which is consistent with the complexity of implementing and evaluating public health interventions. Evidence on public health topics is therefore often derived from cross-sectional studies and quasi-experimental studies (6, 7, 29).

TABLE 3 Methodological quality assessment tools for primary studies included in the systematic reviews by study type*.

Methodological quality assessment tool	Number	%
Cross-sectional studies ($N = 84$)		
NOS adaptation	14	16.7
NHLBI	9	10.7
JBI	7	8.3
AHRQ	4	4.8
ROBINS-I	4	4.8
Assessing risk of bias in prevalence studies	3	3.6
Assessing bias in studies of prognostic factors	3	3.6
EPHPP	3	3.6
AXIS	2	2.4
CASP	2	2.4
MMAT	2	2.4
STROBE	2	2.4
The Downs and Black checklist	2	2.4
Cohort studies ($N = 74$)		
NOS	37	50.0
NHLBI	5	6.7
EPHPP	5	6.7
ROBINS-I	3	4.0
JBI	3	4.0
Assessing bias in studies of prognostic factors	2	2.7
The Downs and Black checklist	2	2.7
Randomized controlled trials ($N = 67$)		
ROB	34	50.7
EPHPP	7	10.4
EPOC	3	4.5
JBI	3	4.5
ROB 2.0	3	4.5
MMAT	2	3.0
NHLBI	2	3.0
PEDro scale	2	3.0
Quasi-experimental studies ($N = 60$)		
ROB	10	16.7
EPHPP	9	15.0
JBI	6	10.0
The Downs and Black checklist	6	10.0
ROBINS-I	5	8.3
NHLBI	3	5.0
NOS	3	5.0
EPOC	2	3.3
MMAT	2	3.3
Case-control studies ($N = 45$)		
NOS	25	55.6
ROBINS-I	3	6.7
NHLBI	3	6.7
EPHPP	2	4.4
QUADAS-2	2	4.4
Qualitative studies ($N = 26$)		
CASP	10	38.5
MMAT	3	11.5
JBI	2	7.7
Mixed-methods studies ($N = 19$)		
MMAT	4	21.0
CASP	2	10.5
NHLBI	2	10.5

*We only present the most common quality evaluation tools (frequency of use ≥2). We only extracted data that were reported in the SRs.

AHRQ, Agency for Healthcare Research and Quality; AXIS, Appraisal Tool for Cross-Sectional Studies; CASP, Critical Appraisal Skills Programme; EPHPP, Effective Public Health Practice Project; EPOC, Effective Practice and Organization of Care Group; JBI, Joanna Briggs Institute; MMAT, Mixed Methods Appraisal Tool; NHLBI, National Heart, Lung and Blood Institute; NOS, Newcastle-Ottawa scale; PEDro scale, Physical Therapy Evidence Database scale; QUADAS-2, Quality Assessment of Diagnostic Accuracy Studies; ROB, The Cochrane Collaboration's tool for assessing risk of bias in randomized trials; ROBINS-I, Risk of bias in non-randomized studies of interventions; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.

Our finding that approximately 70% of SRs evaluated the quality of the included primary studies is lower than what was found by a previous survey of medical journals, reporting that 90% of SRs evaluated the quality of included studies (30). AMSTAR 2 contains an item asking whether the review authors made an adequate assessment of study level efforts to avoid, control, or adjust for baseline confounding, selection bias, bias in measurement of exposures and outcomes, and selective reporting of analyses or outcomes. Using a satisfactory technique for assessing the risk of bias in individual studies that were included in the review is critical (20).

Given the large number of study designs used in public health research, many quality assessment tools are available and there is little consensus on the optimal tool(s) for each specific study designs. For example, for cross-sectional studies and other observational studies, nearly one hundred tools are available (31–35). We also found that researchers did not always correctly distinguish the concepts of methodological quality from reporting quality. For instance, some researchers used reporting checklists (e.g., STROBE, Strengthening the Reporting of Observational Studies in Epidemiology) to evaluate the methodological quality of cohort studies (36) and cross-sectional studies (37, 38). Zeng et al. also reported similar problems (31, 32). Therefore, our

TABLE 4 Approaches used to assess the certainty of the body of evidence in the systematic reviews.

Title of the systematic review	Approach for assessing the body of evidence	GRADE assessment (number of outcomes)[a]			
		High	Moderate	Low	Very low
Vaccination among HIV-infected, HIV-exposed uninfected and HIV-uninfected children: a systematic review and meta-analysis of evidence related to vaccine efficacy and effectiveness	GRADE	4	1	1	3
Prevalence of strongyloidiasis and schistosomiasis among migrants: a systematic review and meta-analysis	GRADE	0	1	4	0
Effects of Housing First approaches on health and wellbeing of adults who are homeless or at risk of homelessness: systematic review and meta-analysis of randomized controlled trials	GRADE	0	4	4	0
Tele-ultrasound in resource-limited settings: a systematic review	GRADE	0	0	1	0
Relationship between caffeine intake and infertility: a systematic review of controlled clinical studies	GRADE	0	0	1	0
Zumba ®, fat mass and maximum oxygen consumption: a systematic review and meta-analysis	GRADE	0	0	1	0
Relationship between exposure to mixtures of persistent, bioaccumulative, and toxic chemicals and cancer risk: a systematic review	GRADE	0	1	0	0
Current strategies and successes in engaging women in vector control: a systematic review	GRADE	6	13	3	1
Do technical aids for patient handling prevent musculoskeletal complaints in health care workers? A systematic review of intervention studies	GRADE	0	0	1	4
Gender-related differences in care-seeking behavior for newborns: a systematic review of the evidence in South Asia	GRADE	0	0	1	1
The impact of financial incentives on physical activity: a systematic review and meta-analysis	GRADE	1	3	3	2
Physical activity interventions in faith-based organizations: a systematic review	GRADE	0	0	0	1
The effectiveness and cost-effectiveness of screening for HIV in migrants in the EUEEA: a systematic review	GRADE	0	1	1	0
The most effective amount of forward movement for oral appliances for obstructive sleep apnea: a systematic review	GRADE	0	0	3	5
Conference equity in global health: a systematic review of factors impacting LMIC representation at global health conferences	GRADE	0	0	0	15
Socioeconomic status throughout life and body mass index: a systematic review and meta-analysis	GRADE	0	0	0	1
Does short message service improve focused antenatal care visit and skilled birth attendance? A systematic review and meta-analysis of randomized clinical trials	GRADE	0	2	0	0
Corticosteroids on the management of coronavirus disease 2019 (COVID-19): a systemic review and meta-analysis	GRADE	0	0	0	12
Utilization of public health care by people with private health insurance: a systematic review and meta-analysis	GRADE	0	1	4	0
Burnout in palliative care nurses, prevalence and risk factors: a systematic review with meta-analysis	OCEBM	NA	NA	NA	NA
Total	-	11	27	28	45

[a]For systematic reviews that used GRADE to assess the quality of the body of evidence for critical or important outcomes, the number of outcomes assessed as high, moderate, low or very low certainty of evidence is presented.

Only 20 out of the 301 included systematic reviews assessed the certainty of the body of evidence. We would like to point out that when reporting results for the GRADE assessments, these assessments are made at the level of individual outcomes, and some included reviews may thus contribute more than one assessment.

GRADE, Grading of Recommendations, Assessment, Development, and Evaluation approach; OCEBM, Oxford Center for Evidence-based Medicine; NA, Not applicable.

findings suggest that SR developers may need additional training and guidance on the selection of optimal tools for assessing the quality of primary studies, particularly non-randomized studies.

4.4. Grading of certainty of evidence

The certainty of the body of evidence refers to the degree of certainty about the veracity of the observations for a specific outcome. Assessing the certainty of a body of evidence form a SR can facilitate an accurate understanding and appropriate application of the evidence by end-users (39). Thus, our finding that only ∼6% of SRs assessed the certainty of the body of evidence is concerning. The main reason may be that public health interventions are often complex, making it difficult to perform such assessments (40, 41). Researchers have found several problems in application of GRADE, currently the most widely used approach for assessing the quality or certainty of the body of evidence in public health: confusion about the perspectives of different stakeholders, selection of outcomes and identification of different sources of evidence (42), and the non-applicability of the specific terminology of GRADE in the field of public health (43). In response to these issues, the GRADE Working Group has established the GRADE Public Health Group (42). In addition, we noted that some SR authors misunderstood the principles of GRADE and applied it at the study level rather than the outcome level (44). Thus, researchers performing SRs may need additional experience and training on the use of GRADE to facilitate its correct and rational use.

Most of the evidence in the SRs that applied GRADE was found to be of low or very low certainty, which may be related to a high risk of bias in the primary studies, heterogeneity of results across the body of evidence, or directness, i.e., that the evidence does not apply directly to the key question of the SR.

4.5. Strength and limitations

To our knowledge, this is the first comprehensive examination of the sources, types and quality of evidence used in SRs of the public health literature. The main strength of this study is the rigorous application of systematic methods in the literature search, screening, and data extraction. Moreover, our study sample (n = 301) is large, it was sampled randomly from all eligible SRs and is up to date, containing SRs published in the last 3 years.

Our study has also some limitations. Our results reflect what was reported in the articles, and it is possible that some SRs were conducted more rigorously than how they were reported, or *vice versa*. Additional information could have been gleaned by contacting the authors of the SRs or by examining the primary studies themselves. Our study only analyzed literature published in English, the findings of this study may not apply to SRs published in other languages. Finally, we used the study design designation made by the SR authors, given the variability of terminology, and it is possible that the types of some studies were misclassified.

5. Conclusion

SRs should always assess quality both at the individual study level, and the level of the entire body of evidence. Investigators in public health need to focus on the robustness of the study design, minimize the risk of bias to the largest possible extent, and comprehensively report the methods and findings of their studies.

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

YX, QG, YC, and RS developed the concept of the study. QG, YX, MR, YL, YS, SW, HLa, JZ, HLi, and PW were responsible for data curation. QG and YX analyzed the data and wrote the original draft of the manuscript. YX, JW, QS, QW, YC, and RS reviewed and edited the manuscript. All authors read and agreed the final submitted 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/fpubh.2023.998588/full#supplementary-material

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EDITED BY
Hubing Shi,
Sichuan University, China

REVIEWED BY
Ezequiel Pinto,
University of Algarve, Portugal
Xiaomin Song,
BeiGene, China

*CORRESPONDENCE
Jingfen Jin
✉ zrjzkhl@zju.edu.cn

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Cardiovascular disease risk perception among community adults in South China: a latent profile analysis

Zhiting Guo[1,2], Yong Yuan[3], Yujia Fu[2], Nianqi Cui[1,2], Qunfei Yu[1], Erling Guo[4], Chuanqi Ding[5], Yuping Zhang[1] and Jingfen Jin[1,6]*

[1]Nursing Department, The Second Affiliated Hospital of Zhejiang University School of Medicine, Hangzhou, Zhejiang, China, [2]Faculty of Nursing, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China, [3]China Mobile (Hangzhou) Information Technology Co., Ltd., Hangzhou, Zhejiang, China, [4]School of Public Health, Hebei Medical University, Shijiangzhuang, Hebei, China, [5]Emergency Department, Changxing County People's Hospital, Huzhou, Zhejiang, China, [6]Key Laboratory of the Diagnosis and Treatment of Severe Trauma and Burn of Zhejiang Province, Hangzhou, Zhejiang, China

Objective: Risk perception, a critical psychological construct, influences health behavior modification and maintenance of individuals with cardiovascular disease (CVD) risk. Little is known about CVD risk perception among Chinese adults. This research examined the profiles of CVD risk perception of community adults in South China, and explored the characteristics and factors that influence their perception of CVD risk.

Method: This cross-sectional study was conducted in Hangzhou, Zhejiang Province, in South China from March to July 2022 and included 692 participants. Risk perception was assessed using the Chinese version of the Attitude and Beliefs about Cardiovascular Disease Risk Questionnaire. Latent profile analysis (LPA) was performed to extract latent classes of CVD risk perception. These classes of CVD risk perception were compared with 10-year CVD risk categories to define correctness of estimation. Chi-square tests and multinomial regression analyses were used to identify differences between these categories.

Results: Three CVD risk perception classes were identified by LPA: low risk perception (14.2% of participants), moderate risk perception (46.8%), high risk perception (39.0%). Individuals who were aged with 40–60 year ($OR = 6.94$, 95% $CI = 1.86–25.84$), diabetes ($OR = 6.26$, 95% $CI = 1.34–29.17$), married ($OR = 4.52$, 95% $CI = 2.30–8.90$), better subjective health status ($OR = 3.23$, 95% $CI = 1.15–9.10$) and perceived benefits and intention to change physical activity ($OR = 1.16$, 95% $CI = 1.05–1.27$) were more likely to be in the high-risk perception class. Compared to absolute 10-year CVD risk based on China-PAR, a third of participants (30.1%) correctly estimated their CVD risk, 63.3% overestimated it and 6.6% underestimated it. CVD risk underestimation was associated with hypertension ($OR = 3.91$, 95% $CI = 1.79–8.54$), drinking ($OR = 3.05$, 95% $CI = 1.22–7.64$), better subjective health status ($OR = 2.67$, 95% $CI = 1.18–6.03$).

Conclusions: Most adults in South China possess a moderate level of CVD risk perception. Advanced age, higher monthly income, diabetes and better health status were significantly related to higher perceived CVD risk. Individuals with hypertension, drinking and better subjective health status were associated with CVD risk underestimation. Healthcare professionals should pay attention to the indicators for different classes and identify underestimation group as early as possible.

KEYWORDS

cardiovascular disease, risk perception, knowledge, public education and awareness, latent profile analysis

Introduction

Cardiovascular disease (CVD) is a major cause of premature mortality and disease burden globally (1). As of 2019, CVD accounts for 46.74% and 44.26% of the causes of death in rural and urban areas in China, respectively, i.e., over two of every five deaths were due to CVD (2). The burden of CVD will continue to increase as China faces the dual pressures of an aging population and the widespread prevalence of metabolic risk factors (2). Risk factor control through evidence-based drug therapy and healthy behaviors are cost-effective public health interventions for reducing CVD risk by up to 80% (3). Nevertheless, recommended CVD preventive medication use and risk factor control have been suboptimal worldwide (4). According to the report of NCD risk factor collaboration, less than half hypertension patients were treated (47% for female, 38% for male) globally, and the control rate was 23% for female, 18% for male (5). In China, the proportion of primary drug use is low in high CVD risk individuals, with the use of blood pressure-lowering and lipid-lowering drugs at 40.35%, 8.25%, respectively (3). Thus, it is crucial to provide more attention to the key barriers of CVD prevention to minimize CVD risk.

Sustainable prevention strategies cannot work effectively without the participation of CVD risk populations. Understanding CVD risk is a prerequisite for adopting a healthy lifestyle and habits conducive to health (6). Risk perception is considered as a critical psychological construct, that affects health behavior change and maintenance (7). A correct risk perception is necessary for an individual to adopt a healthy lifestyle, and risk perception deficiency is considered an additional CVD risk factor (8). Studies have shown that individuals who perceive themselves at a higher risk of CVD are more likely to adopt a healthy lifestyle (9, 10) or demonstrate a willingness to consider future prevention therapy (11). In general, knowledge of the widely promoted risk factors for CVD, such as elderly, smoking, being obese, and high blood pressure, may form the basis of an individual's risk perception (6, 12). Thus, improving knowledge and risk perception is an integral part of behavioral interventions aimed at reducing the incidence of CVD (13). Although there has been considerable research in Western populations, little is currently known about CVD risk perception among Chinese adults.

In regard to CVD risk perception, studies have focused on the measurement, experience, and influence outcomes of risk perception and have emphasized the importance of the accuracy of CVD risk perception (11). Gender, age, education level, socioeconomic status, body mass index (BMI), perceived health status, and other factors have been reported to be associated with CVD risk perception (14–16), while several studies suggest no significant differences for CVD risk perception across age, sex, occupation, and education groups (11, 17). Traditionally, these studies have concentrated on the relationship between variables while ignoring individual differences in CVD risk perception. Although previous studies have applied the single-item risk perception assessment tool, vertical slider scale with numbers, or multi-item measurements, none have reported a cut-off value or classification approach to indicate latent categories of CVD risk perception. Without such categorization, further analysis of the characteristics to distinguish different risk perception categories would be limited. This lack of clarity could affect our ability to identify subgroups of individuals who may be at relatively higher or lower perceived risk for CVD and who may benefit from tailored preventive interventions.

Latent profile analysis (LPA) is a person-centered algorithm that aims to classify individuals into unobserved groupings (latent classes) with similar (more homogeneous) patterns (18). LPA enables us to create and expand theoretical thinking on the existence of various profiles in variables. Applying a person-centered approach to research on CVD risk perception can identify latent profiles that differ from each other in terms of individual perceived CVD risk. In sum, to better understand CVD risk perception and develop targeted risk communication strategies, this study intends to (a) explore CVD risk perception subgroups among community-dwelling adults in South China using LPA, and identify the characteristics of each categories, (b) identify the factors associated with risk misperception compared with objective calculated CVD risk.

Methods

Study design and participants

A cross-sectional survey was conducted in Hangzhou, Zhejiang Province, from March to July 2022. Invitations were issued to patients in the endocrinology and physical examination departments of the second affiliated hospital Zhejiang University school of medicine. We recruited individuals who consent to participate after their hospital discharge. The inclusion criteria were (1) being a Zhejiang citizen; (2) age 20–80 years; (3) having no previous diagnosis of CVD; (4) having a full medical examination report within the last 3 months; and (5) being able to read and speak in Mandarin. The participants with critical illness, mental deficiency, pregnancy, or undergoing treatment for a psychiatric disorder were excluded. After the exclusion of responses with incomplete or invalid answers to the questionnaire, a total of 692 participants were included in the final analysis.

Data collection procedure

Data were collected by well-trained healthcare staff and researchers using the standard protocol and questionnaires with stringent quality control. Before the assessment process, the participants were informed of the topic of the study. A paper-based survey and online survey platform powered by WJX (www.wjx.com) were provided, and participants could choose the one that they preferred. Each participant completed the three parts of the questionnaire, including general information, CVD risk perception assessment, and items for the calculation of 10-year CVD risk. General information and CVD risk perception were self-assessed. If participants were unable to write, the investigators read each item to them, then the questionnaire was completed according to the statements of the participants. The 10-year CVD risk was calculated using an online calculator (https://www.cvdrisk.com.cn/ASCVD/Eval) by the investigator after obtaining indicators from health check report, with the permission of participants. The research was approved by the Ethics Committee of the Second

Affiliated Hospital of Zhejiang University School of Medicine (No. 2022-0280).

Measures

General information

Demographic characteristics included age, gender, height (cm), weight (Kg), marital status, education level, ethnic group, employment status, monthly income, smoking and drinking status, family history of CVD, hypertension or diabetes medical history, and subjective health status. BMI was calculated by dividing weight (Kg) by height (m) squared. Family history of CVD referred to participants' having at least one relative (parent or sibling) with myocardial infarction or stroke (19). Smoking and drinking status was determined by the answer to the question, "What is your current smoking/drinking status?" (1 = never smoked/drank, 2 = ever smoked/drank, 3 = currently smoke/drink). Subjective health status was estimated through the answer to the question, "In general, how would you rate your health status?" (1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = excellent) (19).

CVD risk perception

The Attitude and Beliefs about Cardiovascular Disease (ABCD) Risk Questionnaire was employed to measure people's CVD risk perception, which has confirmed validity in a variety of populations (20–22). The original English questionnaire was developed by Woringer et al. (7); we translated and modified the questionnaire into a Chinese version (ABCD-C) in an earlier study (23). The scale contains 26 items and has four dimensions: CVD-related knowledge (8 items), risk perception (8 items), perceived benefits and intention to change physical activity (6 items), and perceived benefits and intention to change dietary habits (4 items). For each item of knowledge, the correct answer was scored as 1, and an incorrect or "I don't know" answer was scored as 0. Values are summed to create a summary score, for which higher values indicate higher CVD-related knowledge. Answer options for the other three dimensions are presented on a 4-point scale and range from 1 = strongly disagree to 4 = strongly agree; a "not applicable" option was added, with a value of 0. Items 15, 21, and 26 were reverse-coded. The ABCD-C was validated and showed good psychometric properties, with a Cronbach's α reliability coefficient of knowledge, risk perception, perceived benefits and intention to change physical activity, and perceived benefits and intention to change dietary habits scale of 0.801, 0.940, 0.900, 0.830, respectively. In the present study, the Cronbach's α for the four dimensions was 0.670, 0.949, 0.885, 0.833, respectively.

Objective 10-year CVD risk

The 10-year CVD risk was estimated using the China-PAR (Prediction for Atherosclerotic cardiovascular disease Risk) equation (24), which was developed from the gender-specific Cox proportional hazards model (19). Risk factors in the equation included sex, age, geographic region (Northern China/Southern China), urbanization (urban/rural), treated or untreated systolic blood pressure (mmHg), total cholesterol (mmol/L), high-density lipoprotein cholesterol (HDL-C; mmol/L), current smoking (yes/no), diabetes (yes/no), waist circumference (WC; cm), and family history of CVD (yes/no). Based on the cut-off value of the China-PAR in the Chinese guidelines (25), participants were divided into three categories: low risk (<5%), moderate risk (5%−9.9%) and high risk (≥10%).

Statistical analysis

We used LPA to depict the clustering of CVD risk perception using eight dimensions (items) of risk perception as indicators. LPA was performed with the R software package mclust (26) and tidy PLA (27). LPA posits that there is an underlying latent structure that divides a population into mutually exclusive and exhaustive classes (28). We compared model fits on the basis of the Akaike information criterion (AIC), Bayesian information criterion (BIC), sample size-adjusted BIC (aBIC), and the entropy test to determine the number of categories. For these three indices, smaller values indicate a finer balance between model fit and parsimony. High entropy (close to 1) suggests that the bias is minimal for LCA model (29). The bootstrapped likelihood ratio test (BLRT) compares two models with differing numbers of class specifications. A model with fewer latent classes would fit the data better when BLRT does not have a significant test result ($p > 0.05$) (30). The theoretical base for class solutions also was considered in selecting the best number of participant classes (31).

IBM SPSS 26.0 was used to perform descriptive and analytical statistics. Continuous variables were presented as a mean and standard deviation (SD) or interquartile range, while categorical variables were presented as a frequency with the percentage. We used chi-square tests for categorical variables to compare the differences between CVD risk perception groups. The latent classes of CVD risk perception were compared with 10-year CVD risk categories to define correctness of estimation (accurate risk estimation, risk underestimation or overestimation) (32). The mean difference of ABCD-C scores across the latent classes were determined using one-way analysis of variance (ANOVA) and Tukey's multiple comparison test. The effect size partial eta squared ($\eta 2$) was calculated through the sum of squares of the effect divided by the total sum of the squares; $\eta 2 = 0.01$ indicates a small effect; $\eta 2 = 0.06$, medium; and $\eta 2 = 0.014$, large (33). Multinomial logistic regression models with the full information maximum likelihood method were utilized to determine factors related to the level of CVD risk perception, and correctness of risk estimation. Spearman rank correlations were analyzed between the CVD risk perception latent classes and 10-year CVD risk categories. The correlations of $|r| = 0.10$–0.30, $|r| = 0.31$–0.60, and $|r| = 0.61$–1.00 were considered low, moderate, and high, respectively (34); p-values < 0.05 were considered statistically significant.

Results

Characteristics of the participants

Table 1 presents the characteristics of the participants. Of the 692 adults, 414 (59.8%) were female, and those aged 20–<40 comprised approximately half of the sample (49.7%). More than

TABLE 1 Characteristics of the participants ($N = 692$).

Characteristic	*n* (%)
Age	
20–<40	344 (49.7%)
40–<60	227 (32.8%)
60–80	121 (17.5%)
Gender	
Male	278 (40.2%)
Female	414 (59.8%)
Educational level	
Junior school or below	118 (17.0%)
Middle/high school/specialty degree	217 (31.4%)
Bachelor degree or above	357 (51.6%)
Marital status	
Single	174 (25.1%)
Married	518 (74.9%)
Ethnic group	
Han Chinese	679 (98.1%)
Minority	13 (1.9%)
Employment status	
Employed	439 (63.4%)
Unemployed	253 (36.6%)
Monthly income	
<5,000 RMB	314 (45.4%)
≥5,000 RMB	378 (54.6%)
Smoking status	
Current smoking	118 (17.1%)
Non-smoking/quit smoking	574 (82.9%)
Drinking status	
Current drinking	115 (16.6%)
Non-drinking/quit drinking	577 (83.4%)
Hypertension	
Yes	164 (23.7%)
No	528 (76.3%)
Diabetes	
Yes	296 (42.8%)
No	396 (57.2%)
CVD family history	
Yes	60 (8.7%)
No	632 (91.3%)
BMI (Kg/m^2)	
<18.5	63 (9.1%)
18.5–23.9	372 (53.8%)
≥24.0	257 (37.1%)
Subjective health status	
Excellent/good	565 (81.6%)
Fair/poor	127 (18.4%)
10-year CVD risk (%)	
<5	436 (63.0%)
5.0–9.9	169 (24.4%)
≥10.0	87 (12.6%)

CVD, cardiovascular disease; BMI, body mass index.

half of the participants had an education of bachelor or above (51.6%). Most adults (81.6%) reported good or excellent health status. The 10-year CVD risk, using the China-PAR model, showed that only 87 (12.6%) of participants had high risk, 169 (24.4%) had moderate risk, and 436 (63.0%) had low risk.

Latent profile analysis of CVD risk perception

Table 2 shows fit indices for latent profile Models 1–4. The AIC, BIC, and aBIC, which were used to test the goodness of the model fit, decreased continuously from Class 1 to Class 4 and declined the fastest for Class 3. The entropy showed an optimal fit for the four models, ranging between 0.990 and 0.998. The two-class model was excluded due to higher AIC, BIC, and aBIC; and the four-class model also was excluded due to having the lowest entropy. As such, the model with three classes was preferred. The mean score of the risk perception was divided into three classes. Figure 1 shows the distribution of the three potential classes with different participant levels.

Characteristics of classes

Table 3 presents the scores for CVD risk perception for each group. The other three dimensions of ABCD-C are also shown in the table.

Table 4 shows the characteristics of participants in each CVD risk perception group. Except for gender and ethnic group, other characteristics were significantly different among the three classes ($p < 0.05$). Further, a significant positive correlation was found among three latent classes and the 10-year CVD risk ($r = 0.295$, $p < 0.001$).

Class 1, "low risk perception," comprised 14.2% (98/692) of the sample. This class had a low risk perception score (8.50 ± 0.89). Moreover, the participants in this group were younger, had higher education and better CVD related knowledge, reported better health status, and had a lower 10-year CVD risk than those in other groups. In addition, participants with low risk perception had a lower perceived benefit of physical activity and healthy dietary habits and, thus, less intent to change behavior.

TABLE 2 Model fit indices for different models.

Model	AIC	BIC	aBIC	BLRT	Entropy	Category probability	Case number
1-class	11,378.620	11,451.252	11,400.45	–	–	1	692
2-class	8,267.801	8,381.291	8,301.912	0.009	0.988	0.790/0.210	547/145
3-class	5,860.154	6,014.500	5,906.544	0.009	0.998	0.142/0.390/0.468	98/270/324
4-class	4,831.158	5,026.360	4,889.828	0.009	0.990	0.199/0.171/0.383/0.247	138/118/265/171

AIC, Akaike information criterion; BIC, Bayesian information criterion; aBIC, sample size-adjusted BIC; BLRT, bootstrap likelihood ratio test.

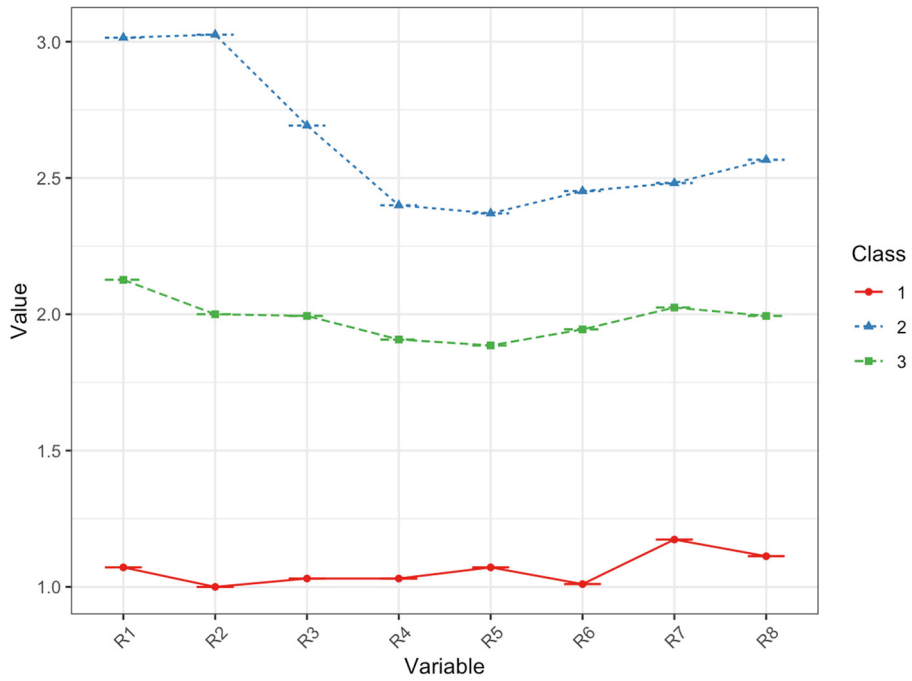

FIGURE 1
Distribution of three potential classes of CVD risk perception.

TABLE 3 Four dimensions of ABCD-C for different risk perception groups ($N = 692$).

Characteristic	Low RP class ($n = 98$)	Moderate RP class ($n = 324$)	High RP class ($n = 270$)	F	P-value	Partial η^2
ABCD-C	43.37 (8.37)^{ab}	52.63 (5.76)^{ac}	58.69 (4.56)^{bc}	261.67	<0.001	0.43
Knowledge (range = 0–8)	6.27 (1.83)^{ab}	5.52 (2.04)^{a}	5.73 (1.80)^{b}	5.68	0.004	0.02
Risk perception (range = 0–32)	8.50 (0.89)^{ab}	15.88 (2.26)^{ac}	21.00 (2.26)^{bc}	1,310.86	<0.001	0.79
Perceived benefits and intention to change PA (range = 0–24)	16.78 (4.88)^{ab}	18.48 (3.36)^{a}	19.05 (2.86)^{b}	15.76	<0.001	0.04
Perceived benefits and intention to change DH (range = 0–16)	11.83 (3.30)^{ab}	12.75 (2.09)^{a}	12.90 (1.82)^{b}	8.85	<0.001	0.03

ABCD-C, Chinese version of Attitudes and Beliefs about Cardiovascular Disease (ABCD) Risk Perception Questionnaire; PA, physical activity; DH, dietary habits.
The same superscripted letters denote a significant difference between each level of variables in the column; $p < 0.05$.

Class 2, "high risk perception," represented 39.0% (270/692) of the sample. The risk perception score of this class was the highest, near twice that of Class 3 and three times that of Class 1, indicating that Class 2 had the highest level of CVD risk perception among the three classes. Most adults in Class 2 had a lower education level and monthly income but a higher BMI and 10-year CVD risk.

Class 3, "moderate risk perception," comprised the highest proportion of the sample, at 46.8% (324/692). This class

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TABLE 4 Characteristics of individuals among risk perception groups ($N = 692$).

Characteristic	Low RP class ($n = 98$)	Moderate RP class ($n = 324$)	High RP class ($n = 270$)	χ^2	*p*-value
Age					
20–<40	91 (92.9%)	164 (50.6%)	89 (33.0%)	103.838	<0.001
40–<60	4 (4.1%)	102 (31.5%)	121 (44.8%)		
60–80	3 (3.1%)	58 (17.9%)	60 (22.2%)		
Gender					
Male	31 (31.6%)	126 (38.9%)	121 (44.8%)	5.617	0.060
Female	67 (68.4%)	198 (61.1%)	149 (55.2%)		
Educational level					
Junior school or below	4 (4.1%)	47 (14.5%)	67 (24.8%)	78.168	<0.001
Middle/high school/ specialty degree	6 (6.1%)	124 (38.3%)	87 (32.2%)		
Bachelor degree or above	88 (89.8%)	153 (47.2%)	116 (43.0%)		
Marital status					
Single	51 (52.0%)	94 (29.0%)	29 (10.7%)	70.002	<0.001
Married	47 (48.0%)	230 (71.0%)	241 (89.3%)		
Ethnic group					
Han Chinese	95 (96.9%)	321 (99.1%)	263 (97.4%)	3.086	0.214
Minority	3 (3.1%)	3 (0.9%)	7 (2.6%)		
Employment status					
Employed	91 (92.9%)	214 (66.0%)	134 (49.6%)	59.718	<0.001
Unemployed	7 (7.1%)	110 (34.0%)	136 (50.4%)		
Monthly income					
<5,000 RMB	23 (23.5%)	139 (42.9%)	152 (56.3%)	32.765	<0.001
≥5,000 RMB	75 (76.5%)	185 (57.1%)	118 (43.7%)		
Smoking status					
Current smoking	1 (1.0%)	56 (17.3%)	61 (22.6%)	23.680	<0.001
Non-smoking/quit smoking	97 (99.0%)	268 (82.7%)	209 (77.4%)		
Drinking status					
Current drinking	6 (6.1%)	62 (19.1%)	47 (17.4%)	9.394	0.009
Non-drinking/quit drinking	92 (93.9%)	262 (80.9%)	223 (82.6%)		
Hypertension					
Yes	3 (3.1%)	72 (22.2%)	89 (33.0%)	36.288	<0.001
No	95 (96.9%)	252 (77.8%)	181 (67.0%)		
Diabetes					
Yes	3 (3.1%)	138 (42.6%)	155 (57.4%)	86.765	<0.001
No	95 (96.9%)	186 (57.4%)	115 (42.6%)		
CVD family history					
Yes	10 (10.2%)	18 (5.6%)	32 (11.9%)	7.712	0.021
No	88 (89.8%)	306 (94.4%)	238 (88.1%)		
BMI (Kg/m^2)					
<18.5	10 (10.2%)	30 (9.3%)	23 (8.5%)	20.172	<0.001
18.5–23.9	70 (71.4%)	173 (53.4%)	129 (47.8%)		
≥24.0	18 (18.4%)	121 (37.3%)	118 (43.7%)		

(Continued)

TABLE 4 (Continued)

Characteristic	Low RP class ($n = 98$)	Moderate RP class ($n = 324$)	High RP class ($n = 270$)	χ^2	p-value
Subjective health status					
Excellent/good	92 (93.9%)	266 (82.1%)	207 (76.7%)	14.297	0.001
Fair/poor	6 (6.1%)	58 (17.9%)	63 (23.3%)		
10-year CVD risk (%)					
<5	95 (97.0%)	211 (65.1%)	130 (48.1%)	76.328	<0.001
5.0–9.9	2 (2.0%)	70 (21.6%)	97 (35.9%)		
≥10.0	1 (1.0%)	43 (13.3%)	43 (15.9%)		

CVD, cardiovascular disease; BMI, body mass index.

showed better risk perception than the other two classes. The perceived benefits and intention to change physical activity or dietary habit was higher in this class than those in Class 1.

Multinomial logistics regression

Table 5 shows the multinational logistic regression results. Compared with low-risk perception class, participants aged 40–60 ($OR = 4.52$, 95% $CI = 1.24$–16.45), monthly income more than 5000 RMB ($OR = 1.45$, 95% $CI = 1.02$–2.05), diabetes ($OR = 4.81$, 95% $CI = 1.07$–21.74), and perceived benefits and intention to change PA ($OR = 1.10$, 95% $CI = 1.01$–1.20) were more likely to be in moderate risk perception class. Participants aged 40–60 ($OR = 6.94$,95% $CI = 1.86$–25.84), married ($OR = 4.52$, 95% $CI = 2.30$–8.90), diabetes ($OR = 6.26$, 95% $CI = 1.34$–29.17), good or excellent health status ($OR = 3.23$, 95% $CI = 1.15$–9.10), and perceived benefits and intention to change PA ($OR = 1.16$, 95% $CI = 1.05$–1.27) were more likely to be in high risk perception class than low risk perception class.

Perceived vs. calculated CVD risk

Compared to absolute 10-year CVD risk based on China-PAR, a third of participants (30.1%) correctly estimated their CVD risk, 63.3% overestimated it and 6.6% underestimated it (Table 6). More than half individuals (50.6%) with high risk underestimated their CVD risk.

We combined individuals who accurately estimate or overestimate their CVD risk together to explore the risk factors associated with risk underestimation, recognizing that underestimation has more detrimental impact on CVD prevention than accurate estimation or overestimation. In the multivariable-adjusted analysis, underestimation of CVD risk was associated with hypertension ($OR = 3.91$, 95% $CI = 1.79$–8.54), drinking ($OR = 3.05$, 95% $CI = 1.22$–7.64), better subjective health status ($OR = 2.67$, 95% $CI = 1.18$–6.03) (Figure 2).

Discussion

The current study is considered the first work that uses the LPA approach to explore subgroups of CVD risk perception among community adults in South China. Our findings determined three latent classes based on the risk perception score of the ABCD-C questionnaire. Close to half of the participants (46.8%) were classified as having moderate perceived CVD risk, while those who were assessed as having low risk perception accounted for the smallest proportion (14.2%). Advanced age, higher monthly income, diabetes, better health status, and having higher perceived benefits and intention to change PA were significantly related to higher perceived CVD risk. Compared to absolute 10-year CVD risk based on China-PAR, only a third of participants (30.1%) correctly estimated their CVD risk. Individuals with hypertension, drinking and better subjective health status were associated with CVD risk underestimation.

Regarding CVD risk perception measurement, a large number of studies have focused on a single-item risk perception assessment tool application, with the choices of "low," "intermediate," and "high" risk (35) or a scale of a 0–100% (36) chance to get CVD within the next 10 years. Importantly, because a person's interpretation of a qualitative risk expression (e.g., high vs. low) can vary, any qualitative statements should be accompanied by a numerical description (37). A lower level of numeracy skill was associated with an overestimation of risk when using a numerical measurement (38, 39). These results suggest that a CVD risk perception level cannot be classified correctly by a single item. In addition, a general reference range for what was considered high or low risk on a scale was absent. The ABCD Risk Questionnaire was developed to measure CVD knowledge and risk perception (7) and has confirmed validity in English (7), Hungarian (20), Dutch (21), and Malay (22). The risk perception dimensions of the ABCD are represented by eight items that describe the perceived susceptibility and severity of individuals for CVD (7). Thus, we use these eight items as a screening tool to classify people through LPA analysis. Our findings demonstrated the distribution of CVD risk perception in Chinese adults, which provided valuable insight into the current status of CVD risk perception.

Further, more than half of the participants were classified into the moderate CVD risk perception group in this study, and

TABLE 5 Multinomial logistic regression on CVD risk perception.

Characteristic	Moderate RP class		High RP class	
	OR	95% CI	OR	95% CI
Age (Ref. 20–<40)				
40–<60	4.52*	1.24–16.45	6.94*	1.86–25.84
60–80	1.80	0.20–16.36	1.79	0.19–16.99
Educational level (Ref. Junior school or below)				
Middle/high school/specialty degree	3.01	0.56–16.37	1.33	0.24–7.38
Bachelor degree or above	1.25	0.19–8.07	4.13	0.59–28.78
Marital status (Ref. Single)				
Married	1.08	0.61–1.89	4.52*	2.30–8.90
Employment status (Ref. Unemployed)				
Employed	0.71	0.16–3.08	1.83	0.40–8.28
Monthly income (Ref. <5,000 RMB)				
≥5,000 RMB	1.45*	1.02–2.05	1.20	0.81–1.77
Smoking status (Ref. No)				
Current smoking	1.61	0.14–18.47	2.43	0.26–23.10
Drinking status (Ref. No)				
Current drinking	2.82	0.79–10.11	2.57	0.91–7.23
Hypertension (Ref. No)				
Yes	1.78	0.39–8.22	3.05	0.66–14.18
Diabetes (Ref. No)				
Yes	4.81*	1.07–21.74	6.26*	1.34–29.17
CVD family history (Ref. No)				
Yes	0.64	0.26–1.59	2.08	0.81–5.29
BMI (Ref. 18.5–23.9)				
<18.5	1.76	0.78–3.97	2.39	0.97–5.85
≥24.0	0.94	0.48–1.87	1.31	0.65–2.66
Subjective health status (Ref. Fair/poor)				
Excellent/good	2.09	0.76–5.72	3.23*	1.15–9.10
10–year CVD risk (<5%)				
5.0%–9.9%	1.64	0.21–12.61	2.30	0.29–18.36
≥10.0%	2.81	0.14–56.94	1.94	0.09–40.29
Knowledge (unit: one score)	0.88	0.75–1.03	0.98	0.83–1.16
Perceived benefits and intention to change PA (unit: one score)	1.10*	1.01–1.20	1.16*	1.05–1.27
Perceived benefits and intention to change DH (unit: one score)	0.99	0.88–1.12	0.95	0.83–1.09

CVD, cardiovascular disease; BMI, body mass index; PA, physical activity; DH, dietary habits; RP, risk perception.
*$p < 0.05$.

39.0% were in the high-risk perception class. Considering that risk perception is recognized as a modifiable determinant of health-related behaviors (40, 41), it is vital to identify subgroups on which to focus to maximize the maintenance of risk perception or improve the level of CVD risk perception through targeted intervention to prevent a decline in the level of risk perception. Our study highlighted that individuals who were older, had a higher monthly income, and had diabetes were more prone to perceive higher CVD risk, which has been confirmed in earlier studies (32, 38, 42). Our study also found that people who perceived better health status were more likely to be in a high-risk perception class, which was inconsistent with the findings in Korean blue-collar workers (15). There may be an interaction between risk perception and personal health status. According to the health belief model (43), people

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who perceived themselves as at higher health risk tend to pay more attention to their health status and to improve their health through behavioral changes. In turn, perceived health status is critical for capturing health risk information. Moreover, due to the cross-sectional design of our study, we could not establish a causal relationship between risk perception and subjective health status. Nonetheless, our findings also highlight the necessity of better health status maintenance in the improvement of CVD risk perception.

TABLE 6 Meshing table between perceived CVD risk and calculated 10-year CVD risk.

Perceived CVD risk	China-PAR risk score			Total
	Low	Moderate	High	
Low	95	2	1	98 (14.2)
Moderate	211	70	43	324 (46.8)
High	130	97	43	270 (39.0)
Total	436 (63.0)	169 (24.4)	87 (12.6)	692 (100)

CVD, cardiovascular disease; China-PAR, Prediction for Atherosclerotic cardiovascular disease Risk; Numbers in absolute, the percentage of total was calculated in column.

Although the majority of the participants (63.0%) in our study were at low 10-year CVD risk based on China-PAR, only 14.2% fell into the low-risk perception class through LPA. This presents a unique opportunity to investigate the potential causes. The time horizon used for risk estimation would influence individuals risk perception (44). Specifically, respondents were more likely to consider their risk "high to very high" when shown the lifetime CVD risk, than when presented the 10-year CVD risk. The items of risk perception assessment used in this study include both short time (10-year, item 12–13) and lifetime risk (item 9–11) to reflect the individuals' risk perception comprehensively. This maybe the critical reason accounting for a lower risk perception proportion in our analysis. Importantly, because a person's perception of risk expression (format, time horizon) can vary, any qualitative statements should be accompanied by the condition description of such a statement.

The accuracy of perceived CVD risk was assessed by comparing participants' risk perception responses to their objective calculated risk derived by the Framingham adult treatment panel (ATP) III model (45), Pooled cohort equations (PCE) (46) or the China-PAR (19). The China-PAR was developed and validated to predict 10-year CVD risk, using data from four contemporary Chinese cohorts. A significant positive correlation was found between three latent classes and 10-year CVD risk calculated by the China-PAR

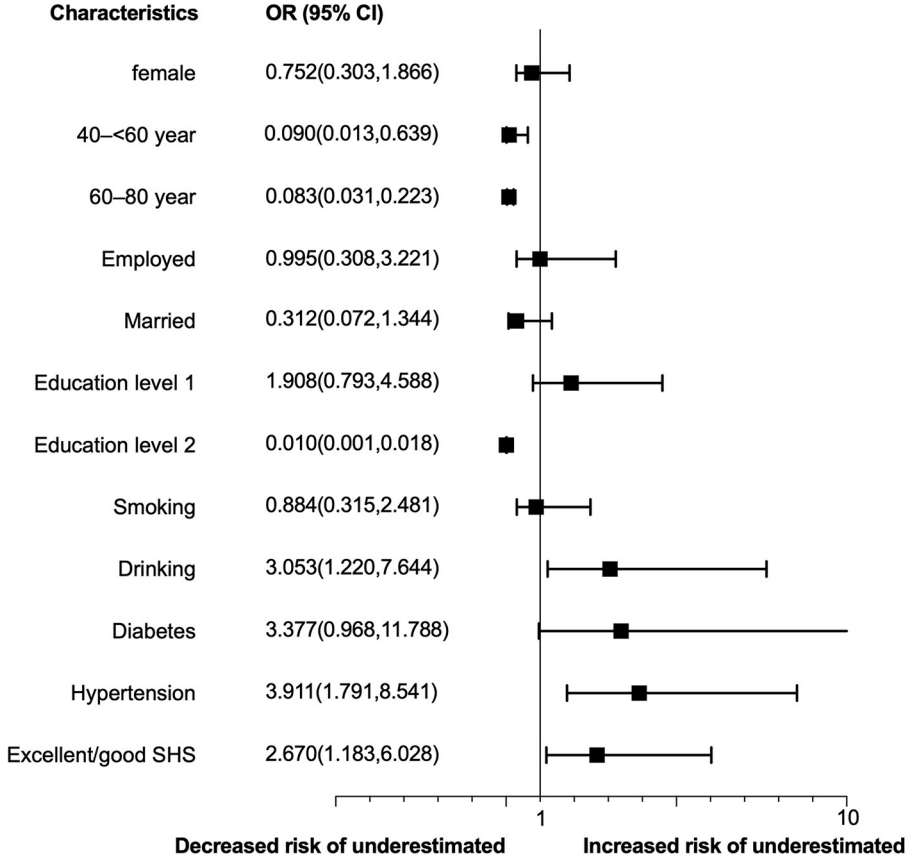

FIGURE 2
Determinants of CVD risk underestimation. Education level 1 refers to middle/high school/specialty degree; education level 2 refers to bachelor degree or above; SHS, subjective health status.

($r = 0.295$, $p < 0.001$), but only 30.1% of participants estimated their CVD risk correctly. Interestingly, more participants (63.3%) overestimated their CVD risk than underestimated (6.6%) it in our study. These findings were consistent with previous studies (risk overestimation: 39%−72.2%) (11, 35). While, a number of studies reported that participants generally have optimistic bias and underestimate their risk of having heart attack or stroke in the future when compared to age and sex matched individuals (40). These findings supported the importance of marked reference and cut-off point, when reporting accurate levels of CVD risk perception. Nonetheless, risk underestimation (too optimistic) had more detrimental influence on health behaviors toward CVD prevention, such as the adherence of medication (40), and lifestyle modifications (47, 48), so as to increase the absolute risk of CVD event. We also revealed that risk underestimation was particularly prevalent among individuals with high CVD risk. Efforts should be made to increase the awareness and accurate perception toward CVD risk in these population, in order to promote proactive health behaviors and self-management of CVD.

To our surprise, hypertension was a determinant of CVD risk underestimation, even though those individuals have had regular medical interaction and lifestyle education (49). Figure 2 showed that diabetes also was a potential factor for risk underestimation. Effective risk communication is essential for promoting public awareness and understanding of potential hazards, as well as empowering individuals and communities to make informed decisions and take appropriate actions to reduce their exposure and vulnerability (50). However, many institutions and organizations have not yet fully integrated risk communication into their policies and practices. As a result, there may be gaps in the dissemination of accurate, timely, and relevant information about CVD risks and their impacts, as well as in the engagement and participation of diverse stakeholders in risk management and decision-making processes. Therefore, it is important to prioritize and support the development of risk communication strategies that are inclusive, adaptive to the contexts of individuals' characteristics, and that integrate it into routine healthcare visits to improve the understanding of CVD risk.

This study has several limitations. First, the study subjects were recruited through convenience sampling from a single tertiary hospital. Although this hospital is a prominent regional central hospital in south China, catering patients from a wide geographic aeras, and serving as a designated site for physical examination for various companies, these population who participate in our investigation were more likely to be younger, higher education level and income. In addition, we also recruited subjects in the endocrinology department, resulting in a higher proportion of participants with diabetes (42.8%) or hypertension (23.7%). Consequently, the generalizability of the study findings may be limited, in particular, the risk perception category cutoff values maybe inappropriate to healthier adults with lower education levels and elderly individuals. Second, we evaluated risk perception based on comprehensive tool covering 10-year risk and lifetime risk, whereas objective CVD risk calculation only followed by 10-year risk. Thus, our conclusions were drawn based on a comparison with 10-year CVD risk. Third, the study was cross-sectional descriptive, limiting our ability to generalize the results related to the interaction between individual risk factors and risk perception. Similarly, we do not explore how individuals form their perception of CVD risk. These limitations highlight the need for future research to address these issues to gain a more comprehensive understanding of CVD risk perception and its impact on preventive behaviors and health outcomes.

Conclusions

As an overview of subgroups of CVD risk perception based on a person-centered approach, this study identifies three classes of CVD risk perception among adults in south China. The majority of participants have a moderate level of CVD risk perception. Advanced age, higher monthly income, diabetes and better health status were significantly related to higher perceived CVD risk. Compared to absolute 10-year CVD risk, only a third of participants correctly estimated their risk. Notably, individuals with hypertension, drinking and better subjective health status were associated with CVD risk underestimation. Healthcare professionals should pay attention to the indicators for different categories and identify underestimation group as early as possible. To improve the accuracy of CVD risk perception, healthcare professionals should focus on effective risk communication among these population.

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 human participants were reviewed and approved by the Institutional Review Board of the Second Affiliated Hospital of Zhejiang University School of Medicine (No. ID: 2022-0280). The patients/participants provided their written informed consent to participate in this study.

Author contributions

ZG: conceptualization, investigation, statistical analyses, and writing of the paper. YY: data curation. YF, CD, and EG: investigation and data curation. NC, YZ, QY, and JJ: methodology, paper review, and editing. JJ: supervision. All authors contributed to the article and approved the submitted version.

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Conflict of interest

YY was employed by China Mobile (Hangzhou) Information Technology Co., Ltd.

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.

Publisher's note

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EDITED BY
Xuelei Ma,
Sichuan University, China

REVIEWED BY
Xiangyang Tian,
China Health Education Center, China
Elena Stanculescu,
University of Bucharest, Romania

*CORRESPONDENCE
Yaolong Chen
✉ chevidence@lzu.edu.cn
Jianqiang Wen
✉ 407954325@qq.com

†These authors have contributed equally to this work and share first authorship

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Developing a questionnaire to evaluate the health information literacy in China

Xuan Yu[1†], Meng Luo[2†], Shouyuan Wu[2], Juanjuan Zhang[2], Qiangqiang Guo[2], Xiaohui Wang[2], Youzhong Tian[3], Zhizhong Zhang[4], Yaolong Chen[1,5,6*] and Jianqiang Wen[7*]

[1]Evidence-Based Medicine Center, School of Basic Medical Sciences, Lanzhou University, Lanzhou, Gansu, China, [2]School of Public Health, Lanzhou University, Lanzhou, Gansu, China, [3]Center for Disease Control and Prevention, Jiuquan, Gansu, China, [4]Health Propaganda and Education Center of Gansu, Lanzhou, China, [5]Research Unit of Evidence-Based Evaluation and Guidelines, Chinese Academy of Medical Sciences (2021RU017), School of Basic Medical Sciences, Lanzhou University, Lanzhou, Gansu, China, [6]WHO Collaborating Centre for Guideline Implementation and Knowledge Translation, Lanzhou, Gansu, China, [7]Gansu Provincial Centre for Development of Traditional Chinese Medicine, Lanzhou, China

Introduction: Health information literacy is critical for individuals to obtain, understand, screen, and apply health information. However, there is currently no specific tool available to evaluate all four dimensions of health information literacy in China. Public health emergencies can present an opportunity to evaluate and monitor the health information literacy level of residents. Therefore, this study aimed to develop a questionnaire to evaluate the level of health information literacy and to measure the reliability and validity.

Methods: The development process of the questionnaire consisted of the determination of questionnaire items, expert consultation, and validation. Based on the National Residents Health Literacy Monitoring Questionnaire (2020) and the 2019 Informed Health Choices key concepts, the researchers drafted the questionnaire, including all four dimensions of health information literacy. Experts in relevant fields were invited to evaluate the draft questionnaire, and revisions were made accordingly. Finally, the reliability and validity of the finalized version were examined in Gansu Province, China.

Results: The research team preliminarily formulated 14 items encompassing the four dimensions of health information literacy. After consulting with 28 experts, modifications were made. A convenience sample of 185 Chinese residents was invited to participate. Cronbach's alpha coefficient was 0.715 and McDonald's omega was 0.739 for internal consistency, and the test-retest intra-class correlation coefficient after 4 weeks was 0.906, indicating that the questionnaire content and measurement structure was relatively stable.

Conclusion: This questionnaire is the first evidence-based assessment tool developed for monitoring health information literacy in China, and it has shown good reliability and validity. It can help to monitor the health information literacy levels of Chinese residents, promote evidence-based decision-making, and guide interventions to improve health information literacy.

KEYWORDS

health information literacy, questionnaire development, reliability and validity, COVID-19 pandemic, evidence-based

1. Introduction

Health literacy is defined as the capacity of individuals to obtain, process, and understand basic health information and services when making appropriate health decisions (1, 2). As a branch of health literacy, health information literacy emphasizes a range of information abilities, including recognizing health information needs, identifying possible sources of information, using them to retrieve relevant information, assessing the quality of information and the application of information in a specific situation, and analyzing, understanding, and using information to make scientific health decisions (3). Unlike health literacy, health information literacy combines both health literacy and information literacy, and it could place more emphasis on the human ability to discover and use health-related information (4). Good health information literacy not only can help people acquire more knowledge related to disease prevention and treatment, maintain a healthy lifestyle, improve doctor-patient communication and smooth doctor-patient conflicts, but it can also reduce the waste of health resources, improve personal health, and promote economic growth and social progress while meeting evidence-based practice (5–9).

As education is one of the hot topics in some developed countries during COVID-19 (10), it is crucial to conduct evaluations that provide evidence-based interventions for future health information literacy education. Several international health information literacy evaluation projects have been conducted or are being conducted, such as the Health Information Literacy Research Project by the US National Library of Medicine (3) and the Daily Health Information Literacy Evaluation Projects for Individuals aged 65 and older in Finland (11). However, in China, national research on health information literacy started relatively late. In 2012, the health information literacy of Chinese residents was assessed for the first time in the monitoring of health literacy among Chinese residents, and was investigated and analyzed separately from the dimension of health information literacy for the first time (12). Nie et al. (13) investigated the health information literacy levels of urban and rural residents in six Chinese provinces based on six items from the Health Literacy Questionnaire and found that these residents had poor health information literacy. However, since this survey instrument does not specifically investigate the health information literacy level of residents, the results cannot comprehensively present the level of health information literacy for Chinese residents.

During COVID-19, several investigations of health literacy were conducted in China; however, only one investigation of health information literacy was conducted on patients who tested positive for COVID-19 (14). This limited population study does not provide a clear understanding of the overall health information literacy level of Chinese residents. While various approaches to evaluating health information literacy exist worldwide, they typically focus on one or two aspects of health information literacy and are not comprehensive (15).

Currently, there are no specific tools to evaluate the four dimensions of health information literacy in China, and most evaluations used individual items extracted from existing questionnaires. Evaluation is a prerequisite for researching and improving health information literacy levels, as it helps us quickly understand the current situation of health information literacy among Chinese residents. In addition to the health-related impact, COVID-19 has had far-reaching effects on China's economy (16, 17), environment (18), and technology (19, 20), and it has led to the circulation of several pieces of misinformation affecting the public's judgement (21). Therefore, the COVID-19 pandemic presents an ideal time to evaluate and monitor the level of health information literacy, as it has affected everyone's lives. This study aims to develop an evidence-based tool for evaluating the level of health information literacy among Chinese residents and to measure the reliability and validity of the questionnaire. The purpose of this new questionnaire is to provide a scientific basis for evaluating and monitoring the level of health information literacy among Chinese residents, and to use this information to help them make optimal health choices in the future.

2. Methods

2.1. Establishment of a questionnaire development working group

The working group for this study comprised decision-makers, researchers, and students from various institutions, including the Health Commission of Gansu Province, the School of Basic Medicine Sciences and the School of Public Health of Lanzhou University, the Gansu Provincial Centre for Development of Traditional Chinese Medicine, and the WHO Collaborating Center for Guideline Implementation and Knowledge Translation. In addition, experts from multiple disciplines such as epidemiology, evidence-based medicine, evidence-based social sciences, public health management, health policy, and health education were recruited to ensure a wide range of perspectives were represented during the development of the questionnaire.

2.2. Development process

The development process of the questionnaire consists of three stages: determining the content of the questionnaire items, expert consultation, and validation.

2.2.1. Preliminary questionnaire items

The National Residents Health Literacy Monitoring Questionnaire (NRHLMQ 2020) and the 2019 Informed Health Choices Key Concepts (2019 IHC KCs) were used as the basis for drafting the pool questionnaire items for the new health information literacy questionnaire in this study. The NRHLMQ 2020 aimed to assess the level of health knowledge and skills of Chinese residents, while the 2019 IHC KCs were developed by IHC (IHC aims to help people to think critically when making informed choices related to health) to help people make evidence-informed health choices based on clear and practical criteria. 2019 IHC KCs through a systematic, transparent, and iterative process involving potential end users and relevant experts, while considering treatment effectiveness and evidence (22, 23). The IHC KCs was

found to be unique among the 22 frameworks examined in a systematic review by Oxman et al. (24), which critical thinking and evidence-based practice as its core.

The items in the NRHLMQ 2020 were the five questions selected by Nie et al. (13) From the 2019 IHC KCs, five researchers (Yu X, Luo M, Wu SY, Zhang JJ, Guo QQ) selected 15 KCs that fit the four dimensions of health information literacy: initiative in obtaining health information; assessing health information; comprehending and applying health information; and screening health information screening. The five reviewers independently working in pairs (Group 1: Yu X & Luo M; Group 2: Yu X & Wu SY; Group 3: Zhang JJ & Guo QQ) selected IHC KCs based on these four dimensions. Disagreements were resolved through discussion or with the help of a third researcher (Chen YL) if consensus could not be achieved. The working group complied with the preliminary items of the new *Health Information Literacy of Chinese Residents During the COVID-19 Questionnaire* via a consensus process among all members.

2.2.2. Expert consultation

In order to further refine the questionnaire, experts from relevant fields were invited to evaluate the first draft in two rounds of consultation. During the first round, experts were asked to rate the necessity, importance, feasibility, and clarity of each item in the questionnaire using a five-point Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, and 5 = Strongly Agree). They were also given the opportunity to provide suggestions for modifying specific items or for the overall questionnaire. Based on the results of this round, items with mean scores of ≥3·5 and full score ratios of ≥0·2 were retained, while those with lower scores were either modified or deleted.

During the second round, experts were asked to evaluate the relevance of dimensions to topics and items using a four-level Likert scale (scores of 1 to 4 indicate irrelevant to very relevant). The item-level content validity index (I-CVI) was calculated and corrected for expert probabilistic consistency (Pc), with modified Kappa statistics (K*) used to assess the validity of the questionnaire. An I-CVI score of ≥0·78 and a K* value between 0·60 and 0·74 were considered indicators of good content validity, while a K* value of >0·74 indicated excellent validity (25).

2.2.3. Validation

2.2.3.1. Study design

The validation study was conducted in Gansu Province, China, from May 26 to June 26, 2021. To ensure a diverse sample, three cities were selected based on factors such as economic development, geographical location, and population growth. Convenience sampling was used to recruit participants, with consideration given to age, gender, urban-rural ratio, and other characteristics. Initially, a target sample size of 140 participants was identified, which was approximately ten times the number of questionnaire items. However, to account for potential missing interviews and invalid surveys, the sample size was increased by 20%, resulting in a target sample size of more than 168 participants.

The inclusion criteria for respondents were: (1) age 15–69 years of age; (2) Chinese nationals; (3) permanent residents who had lived in Gansu Province for 6 months or longer; (4) normal mental status, no serious hearing or vision problems, and ability to communicate in Chinese; and (5) agreement to participate in this study.

2.2.3.2. Survey instruments and quality control

Eight investigators were recruited and trained in groups of two. The purpose and content of the survey were explained to the respondents. After obtaining their informed consent, the investigators read out the questions one by one, and the respondents answered independently or verbally informed the investigators, who then filled in the responses on their behalf. All questionnaires were collected immediately after completion, and the results were entered into the research database using MS Office Excel on the same day. Yu X verified the questionnaires on the same day they were collected to eliminate irrational responses and incomplete questionnaires and ensure the validity of the data.

2.3. Statistical analysis

The degree of expert coordination was evaluated by calculating Kendall's coordination coefficients (W). A significance level of $P < 0·01$ was considered well-coordinated for the criteria of necessity, importance, feasibility, clarity, and the total Kendall coordination coefficient, indicating that the opinions of the experts were well-coordinated and the results were credible. The results of the expert consultation were analyzed using the expert authority coefficient and the degree of coordination. The expert authority coefficient (Cr) is the mean of the judgment basis coefficient (Ca) and the familiarity coefficient (Cs). The data in the validation study were analyzed using SPSS 26.0. Frequency and percentage were used to describe counting data, while mean ± SD was used for quantitative data. Content validity, internal consistency, and test-retest reliability were evaluated using the item-level content validity index (I-CVI), Cronbach's alpha coefficient, McDonald's omega, and intraclass correlation coefficient (ICC), respectively. Structural validity was assessed using exploratory factor analysis (EFA). The answers of the survey participants for all items have been converted into binary variables (correct answers were recorded as "1" and incorrect answers were recorded as "0"). Meanwhile, the outcome variable was divided into "adequate health literacy" and "inadequate health literacy" using a cutoff of 70% of the total score.

2.4. Ethics approval

The study was conducted in full compliance with the principles of voluntariness, confidentiality, and respect for human subjects, protecting the legitimate rights and interests of the respondents. This study was approved by the Ethics Committee of the School of Public Health, Lanzhou University, China (Approval Number: IRB21032901).

3. Results

3.1. Questionnaire development

The research team developed a questionnaire consisting of 14 items to assess health information literacy across all four dimensions. These dimensions included health information initiative (one item adapted from the NHLMQ 2020), evaluating health information (one item adapted from the 2019 IHC KCs), health information comprehension and application ability (ten items adapted from the 2019 IHC KCs), and health information screening ability [two items adapted from the Technical Guideline to COVID-19 Vaccination (First Edition)]. All questions were presented as single-choice questions. The questionnaire item development process is described in detail in Figure 1, and the final version of the questionnaire is included in Appendix 1.

3.2. Expert consultation and content validity

A total of 28 experts in related fields were consulted in the first round, including experts in national health education, health communication, behavioral science, public health policy, health promotion, public policy, disease prevention and control, economics, health career management, epidemiology, basic medical education research, and nutrition and health. The characteristics of these experts are shown in Table 1.

The results of expert self-identification indicated that all 28 experts had high Cr value (0·92), with Ca value ranging from 0·7 to 1·0, and Cs value ranging from 0·8 to 1·0. The degree of expert authority was therefore considered high. The Kendall concordance coefficients (W) values were obtained for each factor, with $W_{necessity} = 0{\cdot}088$, $W_{importance} = 0{\cdot}115$, $W_{feasibility} = 0{\cdot}168$, $W_{clarity} = 0{\cdot}172$, and $W_{overall} = 0{\cdot}139$, and the results were statistically significant ($P < 0{\cdot}01$) indicating consistency among the experts' opinions. However, the consistency was considered moderate to low. Despite this, all items were considered for retention as the mean values across the four dimensions and the full score ratio met the necessary criteria (mean scores of $\geq$3·5 and full score ratios of $\geq$0·2). Based on the expert opinions, modifications were made to the questionnaire such as adding a "Don't know" option to each item and revising the options of five items to better suit the questionnaire's purpose and make the questions easier for respondents to understand.

In the second round of expert consultation, 10 experts in health policy, evidence-based medicine, health education, and other related fields were consulted to further evaluate the content validity of the questionnaire. The results showed that the I-CVI of 12 items was >0·78, indicating excellent content validity. The k^* value of these items was >0·74, indicating substantial agreement among the experts. Item 4 and item 8 were approved by 7 out of 10 experts, with an I-CVI of 0·70 and a K^* of 0·66 after random consistency correction, indicating good content validity. Overall, all items were considered to have at least good content validity and were retained in the final version of the questionnaire.

3.3. Validation of the questionnaire

3.3.1. Demographic characteristics of survey respondents

Out of the 204 questionnaires distributed in the field survey, 198 were returned. Of these, 185 were considered valid, resulting

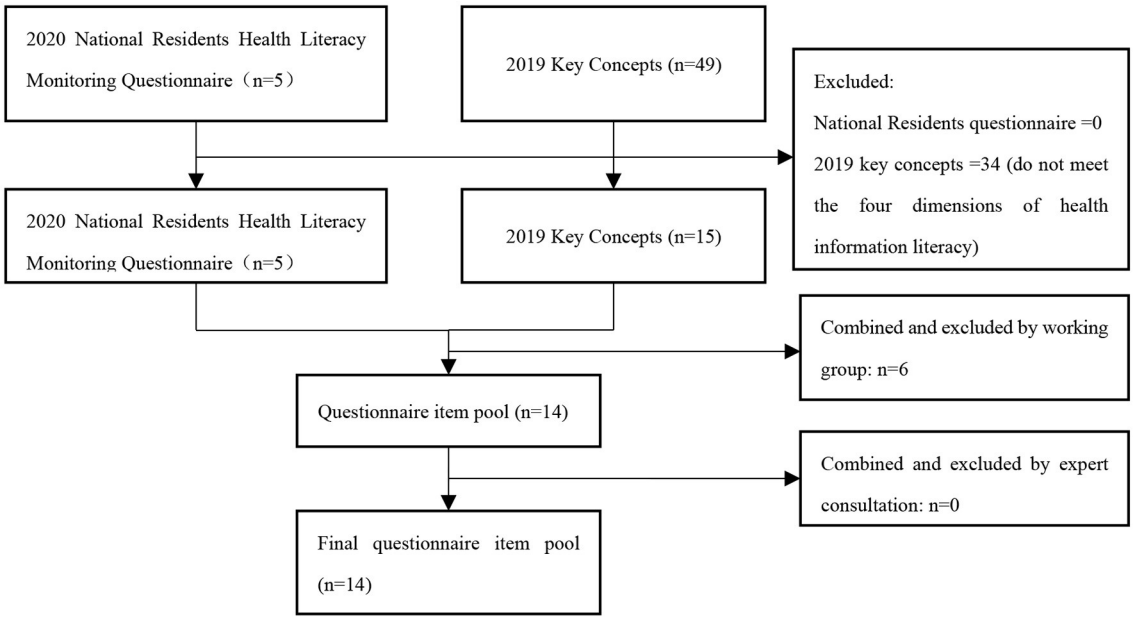

FIGURE 1
Item pool development process.

TABLE 1 Characteristics of the experts in the first round.

Characteristic	No. of Experts	Proportion (%)
Gender		
Male	17	60.7
Female	11	39.3
Age (years)		
26∼30	1	3.6
31∼40	5	17.9
41∼50	9	32.1
51∼60	13	46.4
Education		
Bachelor's degree and below	7	25.0
Master's degree	10	35.7
Doctorate degree	11	39.3
Professional title		
Senior	16	57.1
Vice-senior	5	17.9
Middle	3	10.7
Primary	1	3.6
Others	3	10.7
Workplace		
Gansu Province, China	17	60.7
Outside of Gansu Province, China	11	39.3

in a response rate of 93.43%. The respondents had an average age of 42.73 ± 13.36 years, with a range of 15 to 69 years. The gender distribution was equal. Similarly, the respondents were equally distributed between urban and rural areas, with 50.8% residing in urban areas and 49.2% in rural areas. For further details, please refer to Table 2.

3.3.2. Accuracy rate analysis

The accuracy rate of the questionnaires distributed in urban and rural areas was analyzed separately. If the accuracy rate of a particular item was found to be below 60%, the options with the highest percentage of wrong choices were examined. The questionnaire development working group then discussed whether revisions to the questionnaire items and options were necessary. If the item itself was found to be unambiguous, the original questionnaire item was retained.

The accuracy rates for items 6, 9, and 12 were below 60% for both urban and rural areas in the 185 questionnaires analyzed. After discussions and consensus among the working group, item 12 was modified, while item 6 and item 9 were retained with linguistic adjustments. In the 94 questionnaires from urban areas, item 4 had an accuracy rate of 58.51%, and the option "C" was chosen incorrectly by 53.20% of respondents. Therefore, a semantic modification was made to option "C." In the 91 questionnaires from

TABLE 2 Demographic characteristics of respondents in the validation study.

Descriptions	No. of respondents	Proportions (%)
Gender		
Male	98	53.0
Female	87	47.0
Household registration		
Urban	94	50.8
Rural	91	49.2
City		
Lanzhou	57	30.8
Dingxi	52	28.1
Jiuquan	76	41.1
Age		
15∼19	2	1.1
20∼29	35	18.9
30∼39	45	24.3
40∼49	37	20.0
50∼59	45	24.3
60∼69	21	11.4
Ethnic		
Han	179	96.8
Minorities	6	3.2
Education		
Illiterate or barely literate	5	2.7
Primary school	31	16.8
Secondary school	37	20.0
High school/professional high school/special secondary school	21	11.4
College	32	17.3
Bachelor's degree	45	24.3
Master's degree	11	5.9
Doctorate degree	3	1.6
Career		
Professionals (e.g., teachers/doctors/lawyers, etc.)	19	10.3
Service workers (e.g., caterers/drivers/salesmen, etc.)	10	5.4
Freelancers (e.g., writers/artists/photographers/tour guides, etc.)	2	1.1
Workers (e.g., factory workers/construction workers/urban sanitation workers, etc.)	20	10.8
Company employee	12	6.5

(Continued)

TABLE 2 (Continued)

Descriptions	No. of respondents	Proportions (%)
Government institution employee/civil servants/government staff	36	19.4
Student	10	5.4
Housewife	10	5.4
Others (famers)	66	35.7
Have you been involved in medical science research? (e.g., medical projects, trials, etc.)		
Yes	14	7.6
No	171	92.4
Have you received health science education? (e.g., health lectures, surveys, etc.)		
Yes	129	69.7
No	56	30.3
Are you paying continuous attention to the relevant information of the COVID-19 pandemic?		
Yes	176	95.1
No	9	4.9

rural areas, item 3, 5, 10, 11, and 13 had error rates higher than 60%. The working group concluded that the high error rates were due to a lack of relevant knowledge and not the ambiguity of the items. Therefore, the original item 3, 10, 11, and 13 were retained, and additional clarification was provided for item 5.

3.3.3. Reliability and validity analysis

The results of the consultation on content validity showed that the proportion of experts who rated the necessity, importance, and feasibility of each item as 3 and above (i.e., the items were considered necessary, important, and feasible) ranged from 82.1 to 96.4%, which represents good content validity (content validity index (CVI) > 0.78).

Structural validity was analyzed using exploratory factor analysis. The KMO value was 0.759 ($P < 0.01$), indicating that the data were suitable for factor analysis. Principal component analysis with maximum variance orthogonal rotation was used to extract four common factors with eigenvalues >1, as indicated by the scree plots. The factor loading scores were >0.4, and the cumulative contribution of the variance of the four factors was 51.47%.

Factor 1 included item 1, 2, 5, 7, and 10, and it related to the domain of obtaining health information. Factor 2 included item 3, 9, 12, and 14, and it related to the domain of evaluating health information. Factor 3 included item 4 and 8, and it related to the domain of comprehending and applying health information. Factor 4 included item 6, 11, and 13, and it related to the domain of screening health information. The factor analysis results are presented in Figure 2 and Table 3.

The results of the reliability analysis showed that Cronbach's alpha coefficient for internal consistency was 0.715 and McDonald's omega was 0.739. To assess the stability of the questionnaire over time, a random sample of 18 participants from the 185 valid questionnaires was selected for retesting 4 weeks after the initial survey, representing 10% of the sample. The answers to all items by the participants were converted to binary variables, with correct answers scored as "1" and incorrect answers scored as "0." The ICC was analyzed using a two-way mixed model with absolute agreement as the evaluation type. The test-retest ICC value was 0.906 (95% CI, 0.752 to 0.965), indicating high reliability of the retest and good stability of the content and measurement structure of the questionnaire.

4. Discussion

As the COVID-19 pandemic continues to place increasing demands on the healthcare system, it has become essential for the public to have the ability to evaluate and apply health information. Consequently, health information literacy has emerged as an important area of research. This study is the first to integrate the evidence-based IHC KCs and the Chinese National Health Literacy Monitoring Questionnaire (2020) to develop a tool with strong reliability and validity. It is suitable for monitoring the health information literacy of Chinese residents during the COVID-19 pandemic in Gansu, China. The questionnaire comprehensively evaluates all four dimensions of health information literacy and each item is supported by reliable evidence.

Although high-income countries such as the United States and the United Kingdom implemented health information literacy education programs at the beginning of the 21st century (26), in China, it has only received gradual attention from relevant scholars since 2012, mainly focusing on health information literacy factors and implementation approaches (27). The currently available surveys on health information literacy of Chinese residents are not comprehensive and mostly focus on specific populations, such as university students and the older adult(s), or limited geographic regions (28, 29). Some studies have analyzed the level of health information literacy of Chinese residents using health literacy monitoring data (13, 30, 31). However, these studies do not fully reflect the health information literacy level of the Chinese residents, indicating the need for more effective tools for monitoring.

Monitoring health information literacy is essential to promote evidence-based practice (9). The *Health Information Literacy of Chinese Residents During the COVID-19 Questionnaire* developed in this study suggests that the level of health information literacy is relatively low in both urban and rural areas. Residents tend to rely more on the recommendations of authoritative experts without deeply considering whether the recommendations were supported by high-quality evidence. In the comparison between a new method or technology and an old one, most residents thought that the new method or technology must be better. During the COVID-19 pandemic, the public also believed that taking more of a drug to be beneficial for prevention would further increase its preventive effect.

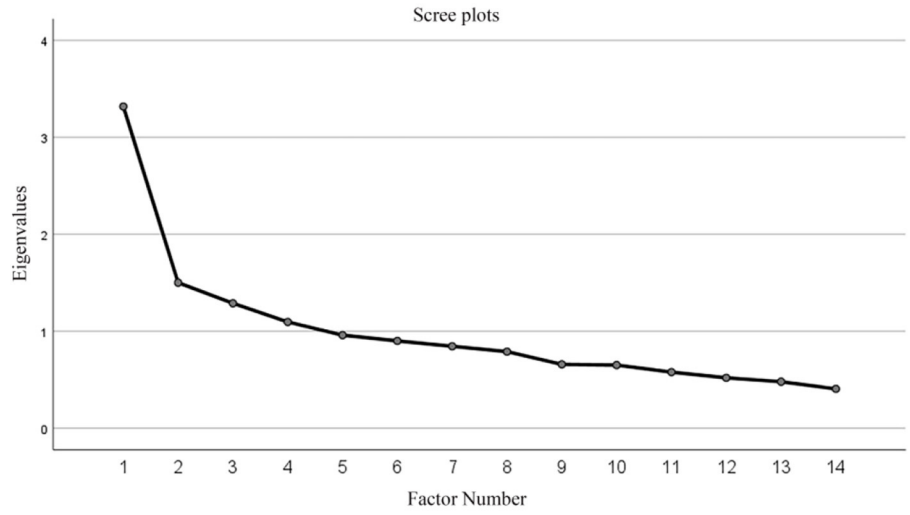

FIGURE 2
Scree plot.

TABLE 3 Factor loadings after rotation.

Item	Factor			
	1	2	3	4
Item 7	0.749			
Item 1	0.709			
Item 2	0.648			
Item 10	0.567			
Item 5	0.452			
Item 14		0.680		
Item 9		0.572		
Item 3		0.532		
Item 12		0.466		
Item 8			0.745	
Item 4			0.682	
Item 6				0.782
Item 11				0.496
Item 13				0.427
Eigenvalues	3.318	1.502	1.289	1.097
Variance contribution rate (%)	17.726	13.004	10.407	10.333
Cumulative variance contribution rate (%)	17.726	30.730	41.138	51.470

It is important to recognize that the findings of this study are based on small sample size and may not be generalizable to the entire population. Therefore, larger and more diverse samples of Chinese residents are needed to validate these results. In the next phase of the study, the working group plans to monitor the level of health information literacy for more than 3,000 residents in Gansu province using this newly developed questionnaire. Based on the results, the working group aims to develop tailored evidence-based health information items for Chinese residents not only in Gansu, but also for other provinces, which can empower the public to make more informed choices regarding their health.

There are some limitations to this study. First, Due to the initial extraction of four dimensions of health literacy using IHC KCs, there is a factor with only two items, which may somewhat diminish the explanatory power of the factor structure and the reliability of the conclusions. Second, the reliability and validity of the questionnaire were based on the population of Gansu Province, and therefore, the applicability of the results to the entire Chinese population cannot be guaranteed. However, our next plan is to focus on the residents of Gansu province to further investigate their level of health information literacy. Second, the sample size of 185 participants may be considered small; however, this study aimed to develop and validate the Questionnaire, and the reliability and validity analyses were conducted appropriately. Third, the study only focused on the level of health information literacy during the COVID-19 pandemic, and did not investigate changes in health information literacy over time or in response to other health crises. Nonetheless, given the unique context of the COVID-19 pandemic, using this questionnaire to investigate public health information literacy is currently the best approach. The working group plans to periodically update the questionnaire, approximately every 3–5 years, to enhance its scientifically rigorous and provide a comprehensive assessment of the public's health information literacy in China.

5. Conclusion

The *Health Information Literacy of Chinese Residents During the COVID-19 Questionnaire* is the first assessment tool specifically developed for health information literacy monitoring in China. This study has demonstrated that the questionnaire shows good reliability and validity, making it a

valuable tool for monitoring the level of health information literacy for residents. This study contributes to the advancement of health information literacy research and provides insights for policymakers and health professionals to develop more effective strategies to improve health information literacy levels among the public, particularly during public health emergencies 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 authors.

Ethics statement

The study was conducted in full compliance with the principles of voluntariness and confidentiality, and respect for human subjects and protects the legitimate rights and interests of the respondents. This study was approved by the Ethics Committee of the School of Public Health, Lanzhou University, China (Approval Number: IRB21032901) and has been conducted. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JW and YC contributed to the conception and design of the study. XY and ML implemented the analysis of data and wrote the first draft of the manuscript. XY, ML, SW, JZ, QG, XW, JW, and YC developed the first draft of the questionnaire. XY, ML, SW, JZ, QG, XW, YT, ZZ, and JW conducted field surveys and entered survey data. All authors contributed feedback on the study results and revised manuscript, contributed to the article, and approved the submitted version.

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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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1068648/full#supplementary-material

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EDITED BY
Hubing Shi,
Sichuan University, China

REVIEWED BY
Timothy R. Muwonge,
Makerere University, Uganda
Charles J. Vukotich Jr.,
University of Pittsburgh, United States
Faiswal Kasirye,
Bowling Green State University, United States

*CORRESPONDENCE
Daraus Bahikire
✉ dbahikire1990@gmail.com

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Risk perception and usage of non-occupational post-exposure prophylaxis among fisherfolk in Ggulwe parish on the shores of Lake Victoria in central Uganda

Daraus Bahikire[1]*, Miisa Nanyingi[1], Christine Atuhairwe[1], Catherine Matama[2], Lesley Rose Ninsiima[2] and Mudarshiru Bbuye[2,3]

[1]Faculty of Health Sciences, Uganda Martyrs University, Kampala, Uganda, [2]School of Public Health, Makerere University College of Health Sciences, Kampala, Uganda, [3]Ministry of Health, Kampala, Uganda

Background: The use of non-occupational post-exposure prophylaxis (nPEP) to prevent HIV acquisition among those exposed as an approach to HIV prevention has expanded in Uganda. Although there are increased efforts to avail nPEP services among most at-risk populations, the usage of nPEP medicines remains low. Therefore, this study examined the risk perception and usage of non-occupational post-exposure prophylaxis (nPEP) among fisherfolk in the Ggulwe fishing parish, Bussi sub-county, Wakiso district.

Methods: A cross-sectional study among adults was carried out from October 2020 to January 2021 in Ggulwe parish, Bussi sub-county, Wakiso district, to examine the usage of nPEP and factors influencing the usage. Data were collected using semi-structured questionnaires, and key informants' interviews were conducted among healthcare providers and the local leadership. The quantitative data were summarized using bivariate and multivariate logistic regression, while the qualitative data were analyzed thematically to enrich the quantitative results.

Results: Overall, 248 fisherfolk encountered an event that required the use of nPEP, and of these, 55/248 (22.2%) were able to use nPEP to prevent them from acquiring HIV. The usage of nPEP among adults in the Bussi sub-county, Wakiso district, was associated with not knowing that HIV can be prevented using nPEP medicines (AOR:0.1, 95% CI 0.03–0.36, $p < 0.001$), lack of knowledge of the existence of nPEP (AOR: 0.3, 95% CI 0.13–0.76, $p = 0.01$), the perception that nPEP can effectively prevent HIV infection after exposure (AOR 0.0586, 95% CI: 0.0177–0.1944, $p < 0.001$), and the community's opinion affecting the willingness to take nPEP (AOR 0.1924, 95% CI: 0.0380–0.9727, $p = 0.0462$).

Conclusion: The usage of nPEP among fisherfolk was low (22.2%). The low usage of nPEP was associated with a lack of knowledge and awareness about nPEP. This effort to improve the usage of nPEP should include community sensitization and HIV infection prevention using nPEP to raise awareness about HIV infection exposures and the risk of HIV infection during non-occupational exposures.

KEYWORDS

post exposure prophylaxis, HIV, Uganda, quantitative data collection and analysis, qualitative data collection and analysis, fishing folks, perception, usage

Introduction

Globally, 76 million people have acquired HIV, and 33 million people have died of HIV/AIDS since the beginning of the HIV epidemic. In addition, 38.0 million (31.6–44.5 million) people were living with HIV at the end of 2019. An estimated 0.7% (0.6–0.9%) of adults aged 15–49 years worldwide are living with HIV, although the burden of the epidemic continues to vary considerably between countries and regions (1). In the first years of the HIV epidemic, condom use was practically the only method available for preventing HIV transmission through sexual contact (2). In recent years, there has been considerable progress with alternative prevention methods, such as post-exposure prophylaxis (PEP) (1). HIV post-exposure prophylaxis (PEP), which is the use of antiretroviral medications for 28 days to prevent HIV acquisition after high-risk exposure, has long been available and is recommended by the WHO, especially among HIV high-risk populations (3).

HIV/AIDS is a leading cause of death in sub-Saharan Africa (SSA), accounting for 71% of the global burden of the infection (4). Different strategies for HIV prevention and control, including early diagnosis, the use of antiretroviral therapy (ART), and post-exposure prophylaxis [PEP], are of considerable interest (5). The Joint United Nations Programme on HIV and AIDS (UNAIDS) stated that HIV prevention must remain the cornerstone of the HIV response to achieve UNAIDS' Fast-Track Strategy to End AIDS by 2030 (6).

In the Uganda Population-based HIV Impact Assessment (2016–2017), the prevalence of HIV infection is lowest (0.2%) among the 15–19-year-old age group and highest (13.6%) among the 50–54-year-old age group (7). This indicates that although remarkable progress has been made in reducing the prevalence of HIV infection in Uganda, the rate of infection is still high. There is a relatively higher prevalence of HIV (10.8%) among the young people living in fishing communities of Lake Victoria (8) compared to the general population, where HIV prevalence among young people is 4.2% (7). The 2007 National Policy Guidelines on Post-Exposure Prophylaxis in Uganda for HIV, Hepatitis B, and Hepatitis C recommend a 28-day course within 36–72 h of exposure to HIV (9). As long as individuals continue to be exposed to HIV, there will be a role for PEP in the foreseeable future. Non-occupational PEP, the majority of which is for sexual exposure (PEPSE), has a significant role to play in HIV prevention efforts (10). Recently, there have been efforts to extend post-exposure prophylaxis among high HIV-risk groups such as female sex workers, fisherfolk communities, and men who have sex with men (MSM) to reduce the risk of HIV infection following occupational and non-occupational exposure (11). Research studies show a significant high demand for post-exposure prophylaxis following exposure to non-consensual sex, mainly among the high-risk population groups (11). In addition, a recent study done in rural Kenya and Uganda showed high retention and adherence to HIV post-exposure prophylaxis (PEP), contributing to the prevention of HIV (12). PEP has been included in the Uganda consolidated guidelines for the prevention and treatment of HIV and AIDS of 2020 (7).

The fisherfolk community is one of the high HIV-risk groups due to their frequent mobility, transactional and commercial sex, multiple sexual partners, high consumption of alcohol, poor health infrastructure, and limited access to health services (13–15). In addition to several interventions rolled out among the fisherfolk community to enhance HIV prevention and control, recent strategies have focused on extending non-occupational PEP in this community (16).

However, there is limited information on the factors associated with the usage of PEP in this community. Therefore, the study aimed to describe factors influencing the usage of non-occupational PEP in a fisherfolk community located on the shores of Lake Victoria in central Uganda.

Materials and methods

Study design and setting

This study used a cross-sectional study design employing both qualitative and quantitative methods of data collection (Figure 1). For the quantitative component, we used a structured questionnaire in which data were captured on exposure and usage of non-occupational PEP by persons who had been exposed to HIV. For the qualitative component, we held interviews with key informants and focus group discussions (FGDs) with the fisherfolk to enrich the quantitative results. Ggulwe fishing parish is a rural place, with a few trading centers found in the Bussi sub-county, Wakiso district, located in central Uganda. The population depends on fishing for a livelihood, with noticeable agriculture taking place. The area was selected for the study because the community is predominantly engaged in fishing and has a high (22%) HIV prevalence.

Methodology implementation

Non-occupational prophylaxis usage in Uganda

In Uganda, HIV-PEP is provided to all eligible clients within 72 h of exposure. Non-occupational exposure is defined as non-occupational exposures including sexual assault (rape and defilement), road traffic accidents, unprotected sex with an HIV-infected person, and unprotected sex with a person of unknown HIV status (7, 17). The Ministry of Health (MOH) Uganda believes HIV infection can be aborted by inhibiting viral replication following an exposure of 48–72 h before the virus can be detected in the regional lymph nodes (10). Provision of nPEP in Uganda is provided for under the 2020 consolidated guidelines for the prevention and treatment of HIV/AIDS (10).

Abbreviations: AIDS, Acquired Immune Deficiency Syndrome; CDC, Center for Disease Control; CDO, Community Development Officer; CI, Confidence Internal; FGD, Focused Group discussion; HIV, Human Immunodeficiency Virus; ICF, Inner City Fund; KI, Key informant; nPEP, Non-occupational Post – Exposure Prophylaxis; OR, Odds ratio; PEP, Post – Exposure Prophylaxis; S/C, Sub county; SSA, Sub-Saharan Africa; TASO, The Aids Support Organization; TasP, Treatment as prevention; UBOS, Uganda Bureau of Statistics; UNAIDS, United Nations Programme on HIV and AIDS; UPHIA, Uganda Population based HIV Impact Assessment; UVRI, Uganda Virus Research Institute; VHT, Village Health Team; WHO, World Health Organization.

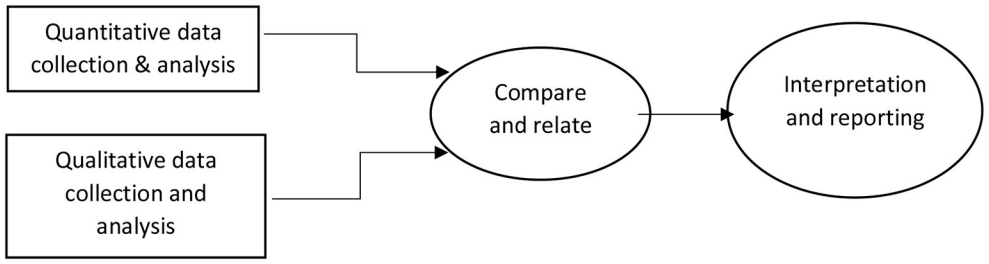

FIGURE 1
Diagrammatic representation of quantitative and qualitative approach.

Data source, study design, and population

A population of 5,011 spread across the five villages was used in the study based on the Uganda National Bureau of Statistics Population Census 2014. A cross-sectional mixed-method study was carried out among fisherfolk communities located along the shores of Lake Victoria in the Ggulwe parish, Wakiso district, from October 2020 to January 2021. To attain quantitative data, we included participants aged 15–49 years selected using purposive and simple random techniques, and for qualitative data, we used healthcare workers and local leaders due to their high level of knowledge on HIV prevention measures and interventions in the area. The sample size was determined using Krejcie and Morgan's (18) formula, and this gave us a sample size of 356 respondents.

Measurements

Our outcome variable was the usage of non-occupational post-exposure prophylaxis, defined as receipt of the following: "Yes" for participants who had taken nPEP within 72 h of exposure and "No" for those who had not. The non-occupational exposure was measured by asking whether the participant had had sexual assault (rape and defilement), road traffic accidents, unprotected sex with an HIV-infected person, or unprotected sex with a person of unknown HIV status prior to the use of nPEP. The usage in this study was taken to be whether a participant utilized PEP obtained from either a government or private health facility after accidental or suspected exposure to HIV. The independent variables consisted of individual factors such as demographics, knowledge about PEP, risk perception, and knowledge of other HIV prevention measures; community-related factors including stigma, perceived effectiveness, and associated negative effects; and health facility-related factors consisting of attitude of health workers and availability of nPEP, and finally, nPEP knowledge among health workers and adherence to prescription guidelines.

Data analysis

Quantitative data analysis

Data were analyzed using STATA version 14.0. Frequencies and their corresponding percentages were used for categorical variables, and mean and standard deviation were used for continuous variables that were normally distributed. The dependent variable was modeled as a binary outcome. Bivariate and multivariable analyses were performed using logistic regression with odds ratios as a measure of association. All variables with a $p < 0.02$ at bivariate analysis were included in the final multivariable model. Factors specified as important based on previous literature were included in the final model. A two-sided significance $p < 0.05$ and a 95% confidence interval were considered statistically significant for the analysis. Measures of association were reported as crude odds ratios at bivariate analysis and adjusted odds ratios at multivariable analysis.

Qualitative data analysis

To enrich and triangulate the quantitative results, we conducted qualitative interviews with men and women in Ggulwe fishing village, Bussi sub-county, Wakiso district. In particular, we held three FGDs, each consisting of six to eight people who were selected randomly from among those community members while maintaining COVID-19 SOPs. The group consisted of both men and women who had encountered or not encountered a situation that exposed them to HIV in the 12 months prior to the study. The FGDs were held within the village meeting rounds in the local language, "Luganda," by two research assistants (DH and MN), both students trained in qualitative research methods. One research assistant (DH) moderated all the FGDs, while the other (MN) audio-recorded the responses and probed where necessary. Each FGD lasted for ∼45 min on average. The moderator encouraged all the group members to ask questions and to provide comments as much as possible on HIV-PEP, knowledge, and usage. For key informant interviews (KIIs), four healthcare providers engaged in the provision of PEP services were purposefully selected and interviewed to elicit their expert opinions on the usage of PEP for HIV prevention. Both FGDs and KIIs were held until saturation was reached. Codes, subthemes, and themes were developed using NVivo V12 Pro, where the transcripts were uploaded and exported to Excel, which helped develop results.

Ethical considerations

The study obtained ethical approval from the research and ethics committee of Uganda Martyrs University. Administrative permission was sought from Ggulwe Parish. We obtained written informed consent from all the eligible participants who were above 18 years. Permission to include participants below the age of 18 was obtained from one or both of the parents/guardians

depending on their accessibility. We then sought the child's assent to participate in the study. Those who declined to participate despite permission from their parents/guardians were not included in the study. The study obtained written informed consent from the adult participants. Participants under 18 years, who are considered emancipated minors, had to provide assent. Participation was voluntary and the study ensured maximum confidentiality considering the intricacy of the study topic. Furthermore, the team was mindful of the anticipated emotional discomfort from the survivors of rape and defilement. In such cases, psychosocial support in the form of confidential counseling and post-trauma support was offered by trained healthcare workers who were members of the study team, and further referrals where required were directed to the available community services.

Results

Sociodemographic characteristics

Table 1 shows that a total of 356 adults were selected and participated in the study. The majority of the participants [162 (45.5%)] interviewed were of the age group between 20 and 30 years, 148 (41.6%) were married or cohabiting, and more than half [185 (52.0%)] had attained a primary level of education. The majority were fishermen/mongers [134 (37.6%)], housewives [55 (15.4%)], peasants [14 (3.9%)], business persons [89 (25.0%)], casual laborers [32 (9.0%)], and others [32 (9.0%)] (Table 1). The results show that half of the participants were female [180 (50.6%)].

TABLE 1 Sociodemographic characteristics ($n = 356$).

Category	All 356, n (%)
Sex	
Male	176 (49.4)
Female	180 (50.6)
Adult age group	
15–20 years	34 (9.6)
20–30 years	162 (45.5)
30–40 years	116 (32.6)
>40 years	44 (12.4)
Level of education	
None	98 (27.5)
Primary	185 (52.0)
Secondary	60 (16.9)
Post-secondary	13 (3.7)
Marital status	
Single	144 (40.4)
Married	148 (41.6)
Separated	55 (15.4)
Widowed	9 (2.5)
Occupation	
Fisherman	134 (37.6)
Housewife	55 (15.4)
Peasant	14 (3.9)
Business person	89 (25.0)
Casual laborer	32 (9.0)
Other	32 (9.0)

Usage of nPEP among fisherfolk in Ggulwe parish, Bussi sub-county, Wakiso district

Table 2 shows that overall, 248/356 (69.7%) adults encountered an event that required the use of nPEP, and of these, 55/248 (22.2%) were able to use nPEP to prevent them from acquiring HIV. The findings show that adults had experienced an event that required nPEP, and only 55 (22.2%) had utilized nPEP. Among the adults that encountered a situation that required nPEP, 17 (6.9%) had been raped, 196 (79.4%) had intercourse with partners whose HIV status was unknown, 17 (6.9%) had sexual intercourse with an HIV-infected person, and 17 (6.9%) had shared sharp objects with HIV-infected persons. Among the cases, the majority [146(59.1%)] reported that it had occurred once, 52 (21.1%) twice, 27 (10.9%) thrice, and 22(8.9%) said they were not sure. A relationship was found between the use of nPEP and being exposed once to HIV infection (OR 0.122, 95% CI 0.016–0.936, $p = 0.044$). Those with a single exposure are less likely to use PEP services. Being exposed multiple times to HIV infection was not statistically significant for nPEP usage.

Factors influencing uptake of non-occupational PEP

In the study, the assumption was that an individual who encountered a non-occupational event with an increased likelihood of HIV infection exposure used the non-occupational PEP. At multivariable analysis, the social demographic factors did not significantly influence the usage of non-occupational PEP. The study found that individuals who did not know that HIV infection could be prevented using nPEP were 90% less likely to use the nPEP services (AOR = 0.1, 95% CI = 0.03–0.36, $p < 0.001$). Similarly, individuals who did not know about non-occupational PEP were 70% less likely to use the services (AOR = 0.3, 95% CI = 0.13–0.76, $p = 0.01$). Furthermore, those individuals who did not know how non-occupational PEP was supposed to be used were less likely to use the services (AOR = 0.1, 95% CI = 0.03–0.19, $p < 0.001$). The results are summarized in Table 3. The results suggest that a lack of knowledge and awareness of non-occupational PEP is associated with a reduced likelihood of using the services.

Results from the key informant interviews

The results from the key informant interviews show a similarity with the quantitative results, with the major themes influencing the uptake of non-occupational PEP.

It was observed that a lack of knowledge of the availability of non-occupational PEP may be hindering its usage among the Ggulwe fishing community in the Wakiso district. Regarding the knowledge of non-occupational PEP, the key informants reported that drugs do not reach the majority of people in the fishing community: one key informant explains in the quote below:

> *"People are not aware of PEP. They are not aware of what can be done after a rape or after any other situation requiring PEP. Some immediately go to the LC leadership without knowing that the raped are supposed to be screened. Even one lady I sent to the health facility for PEP in August 2020 after the rape was not aware that she was supposed to receive PEP simply because she was not aware of it, yet the rapist was on ART. As per the interactions I have always heard, the community is not aware of PEP. I would say the community is at a 25% level of knowledge as regards PEP"* (Female, ART in-charge Bussi S/C).

Another participant cited that there were sensitization campaigns conducted by several organizations to educate communities about PEP.

> *"UVRI did a lot of work to educate people but has never heard anyone say you can find that drug here or there. It is only UVRI that has done commendable work to educate the people about PEP in both Kava-enyanja and Kituufu sub islands but has since not heard of similar community awareness on the PEP. The awareness has not sufficiently sunk into the community. People don't know -how does it work; how does it help. There is a lot of awareness on HIV but it is lacking on PEP. People don't usually use it-I have never heard someone use it, yet as you see, this is an island with many prostitutes, so the awareness is lacking, it's not enough"* KI Councilor, Ggulwe parish.

Knowledge of other HIV prevention measures

The various HIV/AIDS prevention methods cited were male circumcision, abstinence, the use of male condoms, avoiding multiple sexual partners, regular screening for HIV before having sex, being faithful to one sexual partner, and avoiding sharing sharp objects.

The study findings also revealed that the fishing community was given information and supplied with condoms. The health workers also encourage young people to abstain until marriage, although it proves fruitless. One of the key informants explained as follows:

> *"The community knows other prevention but young girls are attracted by money to indulge in unprotected sex. We also give out free condoms but currently out of stock for 1 month. We can even spend 3 months without condoms, we tell clients to get condoms somewhere else or even from VHTs who usually have. On abstinence, people know – but it can't work here. Most of these people leave their families in Kampala and other areas, someone can't abstain from sex for a long period including the youths,"* KI enrolled nurse/M&E officer.

TABLE 2 Situations associated with the usage of nPEP.

Category	Usage of nPEP		
	No (%)	Yes (n = 55, %)	No (n = 193, %)
Were you in a situation that required the use of nPEP?			
Yes	248	55 (22.2)	193 (77.8)
No	108 (30.3)		
Type of situation			
Was raped	17	15 (27.3)	2 (1.0)
Had sexual intercourse with a partner with unknown HIV status	197	36 (65.5)	160 (83.3)
Had sexual intercourse with an HIV-infected person	17	4 (7.3)	13 (6.8)
Shared sharp objects with infected persons	17	0 (0.0)	17 (6.9)
The number of times this situation has occurred			
Once	147	41 (74.5)	106 (54.9)
Twice	52	9 (16.4)	43 (22.4)
More than twice	27	4 (7.3)	23 (12.0)
Not certain	22	1 (1.8)	21 (10.9)

Following HIV preventive measures is futile in fishing communities since people get easy money and are driven to engage in risky sexual behavior.

> *"Also, women in these communities are few and are shared among the available male. Again, there is a lot of alcoholism, a drunkard person can't easily have self-control on who to have or not to have sexual intercourse with, using barriers like condoms,"* KI Councilor, Ggulwe parish.

Availability and attitude of healthcare providers

The following explanations were obtained. One key informant explained the following:

> *"Even one lady I gave nPEP in August 2020 after the rape was not aware, she was supposed to receive PEP because she was not aware of it yet the rapist was on ART,"* KI, ART in-charge Bussi S/C.

From the arguments above, the indications are that little dissemination of WHO guidelines on administering PEP to clients exists. Most of the KIs reported that the community education programs of PEP are few, and they must educate clients on ART. One of the participants explained the following:

> "*One may go to the health facility and find someone with no expertise in dealing with PEP, told to go back. The client may not go back for fear of being known by many people who may disclose one's status in public*," KI, VHT coordinator, Bussi S/C.

The time spent while waiting to receive nPEP was found to be significant. The odds of an adult waiting <30 min to take nPEP were 0.05 times more likely than their counterparts that had not (OR 0.053, 95% CI. 0.004–0.696, $p = 0.025$). Other factors hindering nPEP service usage, such as fear of social stigma, distance to the health facility, refusal by a partner or spouse, and lack of knowledge about nPEP, were found to influence the usage of nPEP. Although 10/55(14.9%) of the clients reported that they had been denied nPEP at the health facilities in the Bussi sub-county, health workers denying clients nPEP because they may not qualify to take it were found to affect its use, and at times it was out of stock.

Health facility-related factors

The key informant interviews revealed that the health workers can provide non-occupational PEP. However, there are hardly any health facilities where these services can be offered, especially to the rape victim. One of the participants explained the following:

> "*Lack of access to the facility especially for kava-enyanja and Kituufu since there are no health centers in those areas, even no private facilities. There are only drug shops which I don't think offer PEP services*," enrolled nurse.

Therefore, with the increase in health facilities, the health workers in the Ggulwe fishing community should be able to provide non-occupational PEP to their clients. In addition, regular health education on the uses of PEP during community outreach programs would not only increase knowledge but also raise awareness among rape victims to prevent them from contracting HIV infection.

Myths and misconceptions about PEP

One key informant (HIV focal person of Bussi HC) said he gave it to someone who tested negative at the end of 3 months. However, one of the key informants explained the following:

> "*Some say that once the health workers give you PEP medicine; you are already HIV positive. This is because it is HIV medicine. Differentiating between PEP and ARVs is a problem. This may be aggravated by disclosure to the partner about one's HIV status so that the negative partner can take PEP after sexual intercourse*," KI enrolled nurse.

However, despite the community myths, most of the respondents did not have adequate knowledge of the use of non-occupational PEP in the prevention of HIV infection after exposure.

Discussion

The study findings show that the level of knowledge on nPEP to prevent the acquisition of HIV was associated with the usage of nPEP. Conversely, while assessing the use of non-occupational PEP in MSM in the USA, Donnell et al. (19) found that 2,037 participants (47.5%) had heard of nPEP, with higher awareness reported at PEP sites (62%) relative to non-PEP sites (40%). nPEP sites had more recognition through advertising (23 vs. 8% at non-PEP sites) and newspapers (62 vs. 48%), whereas non-PEP sites had information from healthcare providers (18% at PEP sites vs. 29% at no-PEP sites) (19). In contrast, the knowledge of nPEP was low among the participants, given the widespread use of treatment for HIV/AIDS in Boston and San Francisco, USA with only 40% of sites without an active nPEP program. In addition, a certain study observed low knowledge of nPEP among young people in Nigeria (20). This implies that if a need arises for nPEP following a non-occupational exposure, many young people may not access services because they do not have the knowledge, thus potentially leading to new HIV infections that could have been averted. Despite the known and published benefits of PEP, this information is known to healthcare providers and policymakers but unavailable to the general public that is required to use this vital service (21).

The gap in knowledge about nPEP in the study area is not a special case as compared to the cited areas of Nigeria, Boston, and San Francisco. Similar approaches to enhance the uptake of this preventive therapy could be applied.

The perceived risk of acquiring HIV/AIDS was not significant in the non-occupational PEP. Similarly, in a study conducted in the USA among MSM, no association was found between the risk of HIV and nPEP use after exposure. Three seroconversions occurred at 384 visits (1.56 per 100 person-years) with nPEP use, compared to 210 seroconversions at 25,550 visits (1.64 per 100 person-years) with no nPEP use (hazard ratio: 0.91, 95% CI: 0.29, 2.86). The use of nPEP occurred more frequently in men with high-risk sexual behaviors. Those who had reported 10 or more partners had almost triple the adjusted odds of nPEP use (aOR 2.9, 95% CI 1.9, 4.4) relative to those who had reported zero to one (19). Significantly increased odds of nPEP use were seen in men with 2–5 and 6–9 partners. Previous studies in San Francisco showed that the odds of nPEP use increased with the HIV transmission of the reported risky sexual behaviors and low use of nPEP in the community setting (22), so the usage of nPEP is consistent with other cross-sectional studies in the USA, with only a small fraction of men reporting the use of nPEP after a high-risk exposure (23). The findings in other areas clearly agree with the study findings in Uganda. Despite the high risk of infection, communities remain reluctant to utilize PEP, and this clearly explains why HIV infections, notably in the fisherfolk communities, continue to soar.

Uganda is a culturally diverse country where culture and health behavior overlap, and it is important for researchers to assess how cultural beliefs and misconceptions might affect nPEP utilization across geographical regions of the country. The opinions of the community were found to influence the willingness of the community members to use nPEP. Many victims of rape would desire to use PEP but fear of being exposed (24). In contrast, a study done in South Africa among students revealed that they would

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TABLE 3 Factors influencing the uptake of non-occupational PEP.

Category	Usage of nPEP					
	Yes ($n = 55$)	No ($n = 193$)	Crude odds ratio (95% CI)	*p*-value	Adjusted Odds ratio (95% CI)	*p*-value
Sex						
Male	21 (38.2)	97 (50.3)	1.0			
Female	34 (61.8)	96 (49.7)	1.7 (0.91–3.08)	0.10	2.1 (0.56–7.78)	0.27
Adult age group						
15–20 years	6 (10.9)	17 (8.8)	1.0		1.0	
20–30 years	28 (50.9)	88 (45.6)	0.9 (0.32–2.50)	0.84	0.7 (0.15–2.91)	0.59
30–40 years	18 (32.7)	64 (33.2)	0.8 (0.27–2.31)	0.68	0.8 (0.17–4.07)	0.83
>40 years	3 (5.5)	24 (12.4)	0.4 (0.78–1.62)	0.18	0.3 (0.03–2.93)	030
Level of education						
None	12 (21.8)	52 (26.9)	1.0		1.0	
Primary	29 (52.7)	105 (54.4)	1.2 (0.57–2.55)	0.62	0.7 (0.24–2.18)	0.58
Secondary	9 (16.4)	33 (17.1)	1.2 (0.44–3.01)	0.78	0.7 (0.16–2.77)	0.58
Tertiary	5 (9.1)	3 (1.6)	7.2 (1.51–34.5)	**0.01**	1.3 (0.12–13.4)	0.83
Marital status						
Single	23 (41.8)	76 (39.4)	1.0			
Married	22 (40.0)	87 (45.0)	0.8 (0.43–1.62)	0.59	0.8 (0.29–2.01)	0.59
Separated	10 (18.2)	30 (15.5)	1.1 (0.47–2.59)	0.83	0.6 (0.16–2.12)	0.42
Occupation						
Business person	16 (29.1)	44 (22.8)	1.0		1.0	
Fisherman	15 (27.3)	75 (38.9)	0.6 (0.25–1.22)	0.14	1.1 (0.24–5.30)	0.87
Housewife	7 (12.7)	35 (18.1)	0.6 (0.20–1.48)	0.24	0.9 (1.99–3.76)	0.84
Peasant	10 (18.2)	20 (10.4)	1.4 (0.53–3.56)	0.51	1.4 (0.34–5.78)	0.64
Other	7 (12.7)	19 (9.8)	1.0 (0.36–2.86)	0.98	0.9 (0.18–4.98)	0.94
Knowledge on nPEP						
Know that HIV can be prevented using nPEP						
Yes	34 (61.8)	38 (19.7)	1.0		1.0	
No	7 (12.7)	87 (45.1)	0.1 (0.03–0.22)	**0.00**	0.1 (0.03–0.36)	**0.00**
Not sure	14 (25.5)	68 (35.2)	0.2 (0.11–0.49)	**0.00**	0.5 (0.18–1.43)	0.20
Knew about nPEP						
Yes	30 (54.5)	29 (15.0)	1.0		1.0	
No	25 (45.5)	164 (85.0)	0.2 (0.08–0.29)	**0.00**	0.3 (0.13–0.76)	0.01
Knew how nPEP is taken						
Yes	32 (58.2)	23 (11.9)	1.0		1.0	
No	16 (29.1)	164 (85.0)	0.1 (0.03–0.15)	**0.00**	0.1 (0.03–0.19)	**0.00**
Not sure	7 (12.7)	6 (3.1)	0.8 (0.25–2.83)	0.78	0.3 (0.05–1.23)	0.09
Risk perception						
Can contract HIV, if extra care is not taken						
Probably yes	18 (32.7)	44 (22.8)	1.0		1.0	
Most certainly	37 (67.3)	149 (77.2)	0.6 (0.32–1.17)	0.13	0.4 (0.17–1.05)	0.06
Other Methods of HIV prevention						
Knew about HIV prevention methods						
Yes	52 (94.5)	181 (93.8)	1.0		1.0	
No	3 (5.5)	12 (6.2)	0.9 (0.24–3.20)	0.83	0.8 (0.15–4.42)	0.80

95% confidence intervals for odds ratios (ORs) are in brackets. Bold indicates statistical significance.

take PEP if they thought they had been exposed to HIV infection, showing a positive attitude toward the use of nPEP (25). Similarly, Donnell et al. (19) established that individuals were willing to take nPEP if they perceived that they were at risk of acquiring HIV. Although there was no difference in willingness to use nPEP, at nPEP sites, 69% of MSM reported that they were very likely to use nPEP after a high-risk exposure, compared to 66% at non-nPEP sites ($p = 0.06$). A study on factors associated with the usage of nPEP among Thai men revealed that a higher proportion of them who intended to take nPEP answered "yes" when asked whether nPEP would reduce their concerns about becoming infected with HIV (86 vs. 65%, $p < 0.001$). There was no difference in the sense of stigmatization between those who did and those who did not intend to take nPEP (26).

This study revealed that participants would recommend the use of PEP to any potential client. PEP is one important means of controlling new infections, especially among people known to have been exposed (17), so making the population aware of the services is key for the prevention of new HIV infections. Conversely, during the qualitative interactions, most of the participants argued that the community should be educated on PEP.

The usage of non-occupational PEP can be increased through health education and promotion. A study by Kroon et al. (26) on the intent to use nPEP among Thai men revealed that participants who intended to take nPEP had more accurate knowledge about HIV transmission and prevention than those who did not. Approximately 90% of MSM in Thailand knew where to buy it and how soon after HIV exposure it should be taken. However, only 43% of those who recommended its use knew that it should be taken for 28 days (26).

Study limitations

The study on risk perception and the usage of non-occupational post-exposure prophylaxis (PEP) among fisherfolk in Ggulwe parish on the shores of Lake Victoria in central Uganda had several limitations that need to be noted.

The LGBTQ concept was neither reported nor given the desired focus because there was no reference legal document with literature on the subject. This limited the extent to which this population was included and discussed in the study.

The sample size of the study was relatively small, which may have limited the generalizability of the findings to a broader population of fisherfolk in different regions. The limited scope of participants might have led to an underrepresentation of diverse perspectives and experiences within the fishing community.

The study heavily relied on self-reported data from the participants, introducing the potential for recall bias and social desirability bias. It is likely that participants provided responses that they believed were more socially acceptable, leading to an inaccurate representation of their actual risk perceptions and PEP usage.

Relatedly, due to resource constraints and logistical challenges, the study was conducted over a relatively short period of time. This timeframe might not have captured seasonal variations or long-term trends in risk perception and PEP usage among the fisherfolk. A more extended study period could have provided a more comprehensive understanding of this interesting area of study.

Furthermore, while efforts were made to ensure cultural sensitivity and local context adaptation, the study's design and data collection methods might not have fully captured the distinctions of the fisherfolk's beliefs, practices, and perceptions related to HIV prevention and PEP. Cultural factors that were not adequately accounted for could have influenced the results.

Finally, the researchers faced challenges in accessing some sub-island villages with limited health facilities, potentially leading to an underrepresentation of these areas in the study. This limitation might have affected the comprehensiveness of the findings and recommendations, particularly in terms of equitable PEP access.

Conclusion

In conclusion, the 22% nPEP usage study sheds light on the critical need for comprehensive strategies to enhance the adoption and effective utilization of PEP within the fisherfolk communities of Ggulwe parish. The low usage was associated with limited awareness and knowledge about the non-occupational PEP.

There is a need to put together new strategies that publicize non-PEP in the general population, especially the sexually active age group.

There is a need to develop a collaborative approach that involves government bodies, beach management units, community-based organizations (CBOs), development partners, fisherfolk associations, local leaders, and village health teams (VHTs). This can be complemented by conducting health education outreach and employing peer educators from within the fisherfolk community.

Relatedly, the timely dissemination of consolidated guidelines for the prevention and treatment of HIV in Uganda is vital as a reliable resource for both healthcare providers and the fisherfolk. This information can immensely contribute to informed decision-making and reinforce the importance of PEP as an integral part of the overall strategy to combat HIV/AIDS.

Equally crucial is the need for equitable distribution of PEP within fisherfolk communities, especially in remote sub-island villages where health facilities are scarce. By extending PEP availability to the last mile, PEP will not only be accessible but will also be effectively utilized. This approach aligns with the overarching goal of leaving no one behind in the fight against HIV/AIDS.

Bottom-line, a community that understands the importance of PEP and its role in preventing HIV transmission is more likely to embrace the treatment and integrate it into their healthcare-seeking behaviors. By fostering a sense of ownership and empowerment within the fisherfolk community, the broader goal of eradicating AIDS becomes more achievable.

Data availability statement

The datasets presented in this article are not readily available because date sets are restricted to the authors.

Requests to access the datasets should be directed to dbahikire1990@gmail.com.

Author contributions

DB conceived and designed the research study, collected data, wrote the initial draft of the manuscript, and responded to reviewers' comments. MN validated the data collection tools, supervised the study, provided guidance and general oversight during the entire course of the study, and also provided input in the review process. CA supported report compilation and performed statistical analyses. CM and LN contributed to the review of the manuscript. MB provided guidance and critically reviewed and revised the manuscript for important intellectual content. All authors contributed to the article and approved the submitted version.

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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 reviewer TM declared a shared affiliation with the authors CA, CM, and LN to the handling editor at the time of review.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1116317/full#supplementary-material

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Sichuan University, China

REVIEWED BY
Rakhmat Ari Wibowo,
Gadjah Mada University, Indonesia
Mark Holland,
Newman University, United Kingdom

*CORRESPONDENCE
Ayazullah Safi
✉ Ayazullah.safi@bcu.ac.uk
Mohammed Gulrez Zariwala
✉ zariwam@westminster.ac.uk

†These authors have contributed equally to this work

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Incentivised physical activity intervention promoting daily steps among university employees in the workplace through a team-based competition

Ayazullah Safi[1*†], Sanjoy Deb[2], Adam Kelly[3], Matthew Cole[4], Natalie Walker[5] and Mohammed Gulrez Zariwala[6*†]

[1]Department of Public Health, Centre for Life and Sport Science (C-LaSS) at Birmingham City University, Birmingham, United Kingdom, [2]Cambridge Centre of Sport and Exercise Science, Anglia Ruskin University, Cambridge, United Kingdom, [3]Sport and Exercise Science, Centre for Life and Sport Science (C-LaSS) at Birmingham City University, Birmingham, United Kingdom, [4]Hartpury University, Gloucestershire, United Kingdom, [5]School of Life Sciences, Coventry University, Coventry, United Kingdom, [6]Centre for Nutraceuticals, School of Life Sciences, University of Westminster, London, United Kingdom

Introduction: The benefits of walking on health and well-being is well established and regarded as the most accessible form of physical activity (PA) that most individuals can incorporate into their lives. Despite the benefits, the impact of a competitive walking intervention combined with a prize incentive in the workplace is yet to be established. The aim of this intervention was to promote PA among university employees through teams-based competition with a prize incentive targeted towards the recommended 10,000 steps per day.

Methods: A total of 49 employees participated and formed eight departmental teams ranging from Senior Admin management, Educational & Social work, Nursing & Midwifery, Sport & Exercise, Health Sciences, Admin Assistant, Library, and IT to compete in a walking intervention. Each team was handed an ActiGraph wGT3X-BT from Monday to Friday to record their walking steps. Steps. Post intervention participants completed an open-ended survey to provide their views about the intervention.

Results: The ActiGraph findings determined that steps increased by 4,799 per day from daily baseline of 5,959 to 10,758 throughout this intervention. The themes from qualitative data showed that the prize incentive and competitive nature of this intervention has motivated staff to walk more, changed their behaviour, enjoyed the team-based competition, and improved perceived productivity in the workplace.

Discussion and conclusion: This intervention increased employees' daily steps by 4,799 and met the 10,000 steps guideline. The 'Health Sciences' team recorded the highest steps 531,342 followed by the 'Education and Social Work' accumulating 498,045 steps throughout this intervention. This intervention with prize incentive demonstrated a positive impact on employees personal and work-based outcomes as well as contributed to the workplace PA, health, and wellbeing literature, and more specifically, to the scarce research focused on university settings.

KEYWORDS

incentive in the workplace, prize, physical activity, employees health and wellbeing, team-based competition

Introduction

Walking has generally been acknowledged as a convenient and free form of exercise that can be integrated into everyday life (1, 2). The benefits of walking are well-established and include reducing the risk of cardiovascular diseases, diabetes, obesity, and depression (3–5). The physical activity (PA) guidelines are established to encourage individuals to engage in regular PA behaviour. Walking is the most accessible form of PA that most individuals can incorporate into their lives (6, 7). The walking guidelines differ regarding the recommended number of steps. For instance, Patel et al. suggested that 70,00 steps per day (8), whereas Wattanapisit and Thaname, recommended 10,000 steps (9). However, steps less than 5,000 are recognised as sedentary (10), while steps between 5,000–7,499 are identified as low active (11). Moreover, steps from 7,500 to 9,999 would be regarded as somewhat active, 10,000 steps are generally classified as active, and 12,500 or more per day is considered as highly active (9, 12). Nonetheless, 10,000 steps per day is generally accepted guideline worldwide (9, 13, 14). A range of workplace walking programmes reported a mixture of findings about health, wellbeing, and methodological approaches (15–18). Despite walking interventions featuring in the workplace, the methods and approaches used are questionable as most of the studies have mainly applied subjective methods for measuring steps (19, 20). However, studies have used more objective measures of accelerometers showed significant effects in step counts for the intervention group compared to the control group ($p < 0.08$) (21–23). Chan et al. recruited participants from five sedentary workplaces and delivered intervention to determine if accelerometer-based intervention increases daily steps instead of the self-reported methods (21). The results revealed average steps increased from 7,029 ± 3,100 to a plateau of 10,480 ± 3,224 and reported a significant decrease in body mass index (BMI), waist circumference, and resting heart rate.

Hallam, Bilsborough and Courten, conducted the 100-day 10,000 step workplace challenge and the results showed small but significant positive effect in symptoms of depression, anxiety stress and wellbeing. The positive effect occurred regardless of participants reaching the 10,000-step goal (24). The study shows the importance of workplace step challenges for employee's health and wellbeing. Macniven et al. conducted the Global Corporate Challenge and Step Count Challenge recruiting over 585 participants from university in Australia. The findings indicated; daily average steps increased from 11,638 steps in week 1 to 13,787 daily steps in week 16 ($p < 0.001$). Although, this intervention had small to non-significant outcome on reducing the weight (−0.12 kg; $p = 0.416$), BMI x (−0.06 kg/m2; $p = 0.314$), and waist circumference (−0.43 cm; $p = 0.082$) but sitting time during work reduced significantly by 21 min per day ($p < 0.001$). However, in this study 92% of participants were meeting the 10,000 steps per day guideline at a baseline level leading to 98% at follow-up (25). This study concluded that such interventions are more attracted to female and younger employees including those who were already active (25). This shows there is a need to reach and target less active and hard to connect groups of employees in the workplace. Furthermore, Niven et al. conducted the Step Count Challenge and results showed reduction in stress and improved productivity (26). Although, the effectiveness of walking interventions is positive for increasing steps across various settings but more high-quality research is warranted in this area (27, 28).

Previous research has concluded the impact of walking combined with other activities or incentives are yet to be established (29, 30). For example, a 26 weeks intervention was designed to assess if financial incentive played a role in improving PA among hospital staff (31). The PA engagement was objectively measured, and intervention was tailored for individual and team-based, with results demonstrating that providing a financial incentive successfully increase the daily step counts (31). The importance of using financial incentives has increased across settings because research has demonstrated that extrinsic motivation is linked with PA participation. For instance, Patel et al. conducted a 13-week intervention to determine if a financial incentive increased team-based competitive step counts (8). The team with the most recorded steps was announced as a winner. The teams that achieved the daily recommended steps were awarded $50 (8). The findings revealed that competitive nature and financial incentives can help motivate teams to walk. However, the daily recommended steps in this study were set to 7,000. Other studies also recommended that offering extrinsic rewards influence social activities within teams that can improve walking among workers in different settings (8, 32).

Previous research also provided a general insight into the impact of step-counts, although most studies have only focused on financial incentives. Moreover, most of the previous research was grounded on the standard economic theory, which commonly accepts that people perform rationally (31, 33, 34). Previous research suggested that social and behavioural economic research design and implementing the incentives have an important influence (8, 35). Studies recommended that behaviour change interventions may be influential when people participate together, especially when socially connected, such as friends, family, or colleagues (8, 36, 37). Previous interventions have limitations such as the influence of team-based competitive intervention is yet to be explored (19). Some studies conducted walking interventions targeting university employees, and results found a significant effect between pre versus post intervention ($p < 0.002$) 23. Similarly, Fountaine et al. evaluated the differences between job roles in university staff, and results established the management staff accumulated significantly more steps than administrators and faculty staff ($p < 0.05$) (38). However, university employees did not reach the recommended number of daily steps. In the previous research, the actual steps taken and what is perceived as daily recommended steps were not recorded (32). Therefore, behaviour change and team-based competitive interventions assessing steps objectively, with prize incentive and exploring the influence qualitatively, may accomplish the gap regarding the walking intervention in the workplace (39). In summary, the existing research indicates that workplace step challenges can enhance PA and daily

steps including positively impacting mental health and some work-related outcomes such as productivity. However, more research with stronger and comprehensive approach is needed. Thus, the aim of this intervention was to promote PA among university employees via a team-based competition with a prize for the winning team targeted towards the recommended 10,000 steps per day to present that steps-challenge intervention can reinforce the promise of workplace walking initiatives.

Methods

Participants

Following an institutional ethical approval, participants were recruited via an opportunistic sample using those who had participated in earlier studies of a broader piece of research from a UK higher education institution (university workplace) in Birmingham, based in West Midlands, England (40–42). All participants had to be adults (>18 years old), and currently employed by the participant university. A total of 49 employees participated in this mixed methods intervention and formed eight teams according to different job roles to compete. Previous research has reported that a single methodological approach is not ideal as the overarching research, may require the combination of methods such as mixed methods. For instance, PA levels can be assessed using quantitative approach while qualitative methods can explore participants of PA and team-based challenge. Therefore, a mixed-methods approach was adopted as it increases the strength and reduces weaknesses of paradigms in qualitative and quantitative research when used in isolation (43, 44). Table 1 provides a summary of the participant teams per job roles and the number of employees participated in each team.

Measures and protocols

The accelerometer used for steps recording was the ActiGraph wGT3X-BT, which is a valid and reliable monitor for measuring PA (40, 41). The ActiGraph can be positioned in various places on the body, such as hip, wrist, wrist, and ankle or even in the pocket. Device positions can affect the monitoring's accuracy, which can impact the accuracy of the data collection (42). For instance, Hasson et al. assessed the validity of PA monitoring, and showed the data of participants who placed the monitor in the pockets were five times higher compared to monitors on hip (45). Due to the varying results, there is no generally accepted position or standardisation for wearing an ActiGraph. In this study, participants were informed that the monitor has to be worn on the wrist like a watch. Previous literature has supported the use of ActiGraph around the wrist because research have shown that participants are more likely remembering to wear the ActiGraph and the results against other body locations were more accurate representation of the steps (46–52). Moreover, due to the nature of the ActiGraph wGT3X-BT it remains sealed, as participants could not see or read their activities data recorded unless downloaded via a software which only the researcher had access to in this study. Therefore, for ActiGraph to function, an ActiLife, software version 6.13.3 was required for initialisation and downloading the data. Previous research has conducted to assess the effectiveness of using the wearable activity trackers-based (WAT) interventions supported in behaviour change techniques (BCT) in improving PA levels and reported positive findings regarding promoting PA levels (53, 54). However, Liu et al. concluded that WAT and pedometers could results in increasing PA levels but over a short period of time (55). The steps data in this study were recorded for 1 week as a baseline where participants were informed to wear the ActiGraph and conduct their typical activities as usual. Subsequently the intervention was implemented for 7 weeks and the data for each week was collected. Post intervention, teams were sent a qualitative open-ended survey to complete to understand their experience and perspective about the impact of this intervention.

TABLE 1 The breakdown of participants.

Teams per job roles	Number of staff participated in the intervention
Senior Admin management	4
Educational & Social work	7
Nursing & Midwifery	8
Sport & Exercise	3
Health Sciences	8
Admin Assistant	4
Library	5
IT	10

For a department to be eligible to participate, a minimum of three individuals were required to compete. If there were more than three people in one team who wished to participate, they had the option to share the participation across the intervention period. For instance, one could decide what specific week to compete in the 10,000 steps challenge. The procedure was that each team had to nominate a leader responsible for collecting and returning the ActiGraph weekly. The researcher would visit every office and hand out the ActiGraph at 8:30 am, and the ActiGraph would start recording the data at 9:00 am on Monday till 17:00 on Friday. This was to represent a typical working day/week. The ActiGraph would then be collected after 17:00 on a Friday from offices. Teams were to compete against each other using a generic league format across the 7 weeks, with each 'match' accumulating the total steps from teams to form respective results. Table 2 provides the breakdown of weekly fixtures for the 7 weeks for each team.

Teams were awarded 1-point for each day they as a team accumulated 10,000 steps. The team who accumulated the most steps in the week were awarded an additional 3-points for winning the 'match' in that specific week. Participants were aware that the team had an award with the most steps taken at the end of the intervention (i.e., winner of the league). There was also a weekly update on the league, updating the daily and total steps and points accumulated, showing teams winning on that particular week as a form of incentive as previous research suggested that social comparison through leaderboards or similar processes can help promote PA levels and competitiveness among teams (56–58). The league update was emailed to the leader of every team weekly and then the team leader would share the results with rest of the team. Research also reported that behaviour change interventions may be more influential when people participate together, especially when socially connected, such as

TABLE 2 The breakdown of teams and fixture during the 7-week steps challenge.

	Sport & exercise	*vs*	Academic services management
Week 1	Library	*vs*	IT
	Health Sciences	*vs*	Nursing & Midwifery
	Education & Social Work	*vs*	Admin assistants
	Sport & Exercise	*vs*	Library
Week 2	Academic Services Management	*vs*	IT
	Admin Assistants	*vs*	Health Sciences
	Nursing & Midwifery	*vs*	Education & Social Work
	Sport & Exercise	*vs*	IT
Week 3	Academic Services Management	*vs*	Nursing & Midwifery
	Library	*vs*	Admin Assistants
	Education & Social Work	*vs*	Health Sciences
	Sport & Exercise	*vs*	Admin Assistants
Week 4	Academic Services Management	*vs*	Health Sciences
	Library	*vs*	Education & Social Work
	IT	*vs*	Nursing & Midwifery
	Sport & Exercise	*vs*	Nursing & Midwifery
Week 5	Academic Services Management	*vs*	Education & Social Work
	Library	*vs*	Health Sciences
	IT	*vs*	Admin Assistants
	Sport & Exercise	*vs*	Education & Social Work
Week 6	Academic Services Management	*vs*	Admin Assistants
	Library	*vs*	Nursing & Midwifery
	IT	*vs*	Health Sciences
	Sport & Exercise	*vs*	Health Sciences
Week 7	Academic Services Management	*vs*	Library
	IT	*vs*	Education & Social Work
	Admin Assistants	*vs*	Nursing & Midwifery

friends, family, or colleagues (8, 36, 37). Providing a weekly update about the accumulated steps was to ensure participants were aware of how many steps they had taken each day and on that specific week and to plan accordingly for the next competition in subsequent weeks during intervention period. Table 2 provide the breakdown of weekly fixtures for the 7 weeks intervention for each team.

Statistical and thematic analysis

Before the data analysis, teams were categorised according to their departmental names. The descriptive statistics of ActiGraph data is analysed as total baseline and intervention daily steps. Additionally, qualitative data was analysed via thematic analysis (TA) and presented as themes, sub-themes, and examples from the raw data. The TA is an approach that identifies, organises, allows interpretation, and reporting themes that are instigated from the set of data (53, 54). Furthermore, TA provide the impact of a given activity from participants' perspective (59). Therefore, TA was conducted, and the six-step framework was considered an appropriate approach for qualitative data analysis for this intervention (54). Previous research supported and recommended using the six-step framework and regarded it as an effective approach when analysing data, as it provides a structure for conducting analyses through stages (59). This intervention also used the commonly applied trustworthiness model, which is regarded as the most fitting for the research purpose (53, 56). For instance, the model of trustworthiness for the results, consisting of five conditions: credibility, dependability, conformability, transferability, and authenticity, combined to construct trustworthiness (60). Furthermore, all data was member checked from the raw data through to complete analysis for data saturation.

Results

Figure 1 shows the overall differences between baseline and intervention daily steps, and the differences between the baseline and intervention steps per each participant team according to the job roles. Table 3 highlights, themes, sub-themes, and examples from the raw data with the number of teams.

The baseline steps data shows that employees were not meeting the 10,000 daily steps guideline and recorded an average of 5,959 steps per day as a baseline. The intervention data has shown that the average employees' daily steps has increased to 10,758. Five participants teams shown to be meeting the recommended guideline of 10,000 steps per day, with the "Health Sciences" recording the highest daily average 15,193 steps per day followed by the Education and Social Work team who recorded 14,092 steps per day. The Sport and Exercise team recorded the least average steps per day (6318) followed by the Academic Service Management who recorded 8,430 steps per day.

With respect to the qualitative findings, a total of eight themes with several sub-themes were identified from the raw data providing an insight into employees' perspectives about their participation in this intervention.

Discussion

The baseline data demonstrated that participants were not meeting the 10,000 daily steps guideline. The findings of this intervention also suggests that this intervention increased the step counts towards the recommended daily allocation, such as increasing daily steps by 47,999 from baseline of 5,959 to 10,758. The improvement could be due to the nature of this intervention being a team-based competition with weekly incentives to compete and a prize for the winning team at the end of the intervention. It is also possible that the ActiGraph itself may have served as a reminder for participants to be more active. This may have changed employees' behaviour and motivated them to go for a walk, visit colleagues rather than emailing/phoning or take stairs instead of lifts in the workplace. The present findings support previous research, suggesting

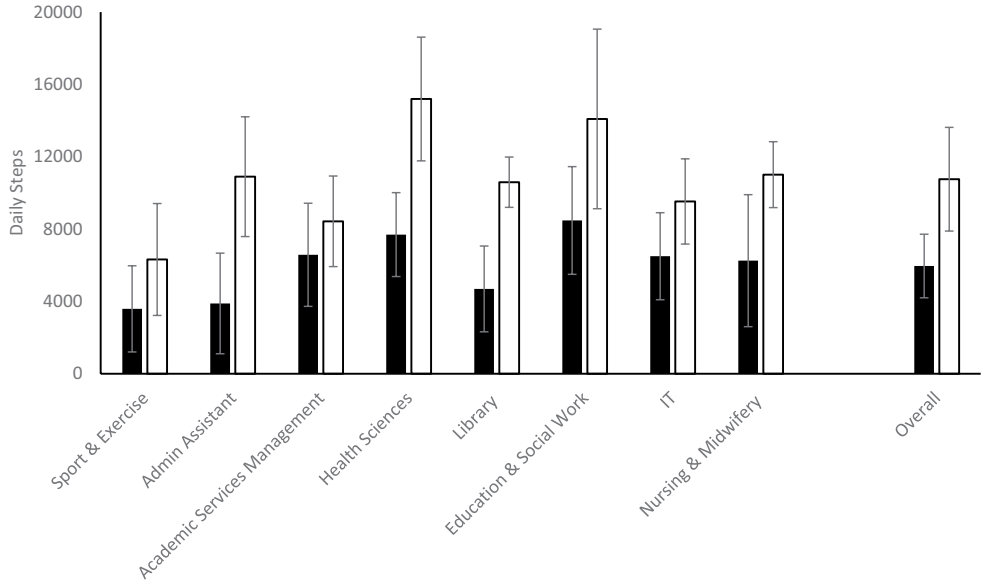

FIGURE 1
The mean and standard deviation (SD) of daily steps across the different participant groups and overall. Black bars=baseline; white bars=intervention.

team-based competitions with extrinsic rewards increase daily step counts (31, 32).

Overall, employees accumulating over 10,000 steps daily in this intervention. Though, discovering the differences between the baseline data and intervention among teams was important to identify if this intervention has improved daily steps between job roles and if any team have met the recommended steps guidelines as detailed in Figure 1. The number of steps appeared higher during this intervention than the baseline data as five departments were meeting the recommended steps guideline of 10,000 steps, with 'Health Sciences' recording the highest daily steps of 15,193. The increased number of steps among all teams could be due to the competitive nature of this intervention's that staff may not wanted to lose against another team. The outcome of this intervention supports previous research suggesting that the competitive nature of intervention motivated staff not to give up and lose to other teams (8, 32). Another potential reason for step increment could be the prize incentive at the end intervention for the winning team. Our findings also align with previous research, suggesting that offering rewards can result in promoting PA participation and improves health (57, 58). Moreover, teams' recording different steps could also be because of their job roles ranging from academics to technicians to management and administration. Indeed, some jobs may have been more physically demanding than others. For instance, the 'Academic services management' job requires staff to be sedentary, whereas the IT team requires staff to move around the building for IT-related issues. Despite the increase in daily steps, not all teams met the 10,000 steps guideline but making comparisons with baseline data shows a positive increase in daily steps. Participants from the winning teams were awarded £10 voucher each to 'Mr. Mulligans'. They arranged a day to visit together for an indoor fun game and lunch as a team. The present findings support previous research suggesting, teams-based competition with an award incentive increased PA levels and improved health and well-being (31, 32).

With respect to the qualitative findings, a total of seven themes with several sub-themes were identified from the raw data providing an insight into employees' perspectives about their participation in this intervention. All eight teams suggested this intervention had motivated them to walk more for different reasons, including enjoyment, health, winning, and perceived productivity. This shows that although some participants who were not reaching the 10,000 steps might still feel the benefits of participating in a competitive intervention, they may have led to increased step counts, relatedness to other team members, and enjoyment. Previous research determined that being autonomous, extrinsic, and intrinsic motivation can lead to increased exercise participation (61, 62). Therefore, introducing a team-based competitive intervention might be an ideal for promoting active behaviour in the workplace among employees. The extrinsic motives such as monetary prize at end of intervention for the winning team could be associated with participants motivation, competitiveness, and behaviour change towards PA engagement. For example, participants stated that; *"The whole team was competitive, and everybody just wanted to win, and we kept walking more."* This supports previous research, concluding that extrinsic motives are linked with PA/exercise participation with favourable outcome (63, 64). Moreover, participants in this intervention stated that; *"We as a team never go outside at lunchtime, but with the challenge, we have tried to do this every day. It motivated us as a whole team to walk more."* Employees never went outside during lunchtime, but this intervention motivated them to go outside as a team for a walk. Thus, positive effects on employees and changing behaviour from sedentary to active may have contributed to their health, wellbeing, perceived productivity, and served as an alternative strategy for teams to be active.

Previous literature mainly focused on participation, adherence and assessing variables in age, gender, culture, and tended that sport/PA competitive nature is typically for youth (45). Whereas, Bell et al. and Davey et al. noted, adults are likely to report competition as an essential

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TABLE 3 Employees perspectives about participating in the team-based steps challenge intervention.

Themes	Sub-themes	Selected quotes from employees	Number of teams
	Team	*"We as a team never go outside at lunchtime but with the challenge, we have tried to do this every day. It motivated us as a whole team to walk more.*	8
Motivation	Encouragement	*"It encouraged us to take longer routes rather than quickest.*	7
	Stairs	*"We were motivated and started to take the stairs instead of the lift.*	4
Competition	Challenge	*"The whole team was competitive, and everybody just wanted to win, and we kept walking more."*	8
	Healthy	*"Nice to be involved in such a healthy and shared competition"*	4
	Interesting	*"It was an interesting experience as we were never involved in such an activity before."*	3
	Enjoyable	*"We felt excited, and it was fun to get involved in a workplace challenge and compete with other departments"*	7
Enjoyment	Fun	*"It was great fun partaking in this competition, absolutely loved it"*	3
	Excited	*"The whole team was very excited, and we kept talking about it all the time"*	3
Active	Fitness	*"We feel, it made us much fitter than before, and we started to take the stairs more often"*	6
	Walking	*"We got up and walk around more than we might have done otherwise"*	8
	Walking meetings	*"We were trying to take more walking meetings to record more steps and be active as we saw the positive effect"*	5
Productivity	Alert	*"I think the challenge helped improved our productivity and we felt alert all the way from the start to end of each week"*	5
	Productivity	*"It made us more productive because we would go for a walk as a team and still manage to get our work done on time"*	4
	Refreshed	*"This challenge helped us by regularly walking around the building or outside which helped kept us fresh throughout the day"*	5
	Breaks	*"The 10,000 steps challenge gave us the opportunity to take regular breaks which really helped us in a working day"*	7
	Sedentary behaviour	*"We have been conscious of sitting for a long time in the workplace. This intervention has changed our behaviour towards walking, now we look for an excuse to go for a walk in the workplace"*	8
Behaviour change	Consciousness	*"It made the team realise there are many benefits to walking and getting up within the working day and moving around is important. Getting fresh air throughout the day definitely helped. This challenge really changed us for better"*	5
	Communication	*"Improved our communication and we kept planning as to who wears the tracker and when and also, we were more inclined to speak to each other about non-work-related activity, something we never done before"*	6
	Gym	*"There has been noticeable difference in overall health and wellbeing during this period and the team felt this is necessary to continue and some colleagues have actually joined gym and started to run and walk more often, thanks to this intervention"*	2
Future incentives	Health and wellbeing	*"We would be keen in participating in more interventions like this within workplace, which would improve our health, and wellbeing"*	8
	Friendly	*"We will definitely participate again. It was an enjoyable challenge and was nice and friendly competition in the workplace"*	5
	Competition	*"It was an enjoyable experience, and everybody agreed they would partake in the same or something similar competitive programme in the future"*	8

factor for engaging in action (65, 66). Thus, this intervention provides a new concept of providing team-based competitive intervention that could improve PA levels, lead to enjoyment and perceived productivity and behaviour change among employees in the workplace. Additionally, this intervention positively contributed, changed behaviour from sedentary to active and raised consciousness about the importance of PA engagement and its impact on health and well-being among employees. Employees noticing the positive outcome during this intervention has led them to join gym membership, started walking and running to work, and continuing the active behaviour was considered an important. This supports previous research suggesting that change includes consciousness-raising, and this is regarded as one of the most important factors for behaviour change to occur (67). Though, changing behaviour is not simple, but making individuals' aware of the pros, cons, and potential consequences of their actions on health, wellbeing and providing alternatives may help them contemplate as such was the case in this intervention as outlined by participants; *"It made the team realise there are many benefits to walking and getting up within the working day and moving around is important. Getting fresh air throughout the day definitely helped. This challenge really changed us for the better."* After consciousness-raising, employees started to find alternatives for achieving more steps, such as conducting walking meetings and walking to colleagues' desks rather than emailing, to take more steps than the team they were competing against. This shows that this intervention

contributed to employees' creative thinking and made them aware of the alternatives of meetings and being active rather than conducting usual meetings or emailing in a sedentary manner. Employees walking to colleagues' rather than emailing could positively change the sedentary behavioural culture in the workplace as this may have encouraged them to walk more than sitting for a prolonged time. Employees being motivated and competitive throughout this intervention has positively changed their behaviour from inactive to active. The present findings contributes to the Transtheoretical Model (TTM) (68), Self-Determination Theory (SDT) (69) and Social Ecological Model (SEM) (70). The findings of this interventions highlighted that employee's behaviour changed from sedentary to active and reported improved health and wellbeing and took time out to go for a walk during lunchtime or conducting a walking meeting leading to connectedness and relatedness with colleagues and people's behaviour is not merely influenced by intrapersonal characteristics but also by various social factors which evidenced in this intervention. Therefore, there is a need for future research to investigate the walking interventions in the workplace considering applying a combination of behaviour change theoretical framework such as TTM, SDT and SEM.

Limitations and future directions

Future research could build upon the framework of this intervention and the current findings can be generalised to other settings. Future team-based friendly competitive activities research is needed across settings and among university employees. Although all teams did not meet the 10,000 steps guideline, this intervention's recorded steps have improved between teams and demonstrated the positive impact of competitive team-based intervention with prize incentives in the workplace. Despite the present intervention revealing useful findings, it is not without limitations. One of the key limitations of this intervention were that it did not have a follow-up study to evaluate if employees continued walking as teams in lunch times, taking stairs instead of lifts or conducting walking meetings instead of usual seated meetings or to assess if their active behaviour has relapsed when the intervention ceased. However, the possible explanations for not conducting the follow-up study were due to the COVID-19 pandemic, and national lockdown in the United Kingdom as most staff, especially the university employees had to work from home during this period.

Conclusion

In summary, this intervention has increased employees' daily steps by 4,799. The 'Health Sciences recorded the highest steps of 531,342 followed by the 'Education and Social Work' team accumulating 498,045 steps throughout this intervention. Despite improving step counts in all teams and sparking a positive atmosphere in the workplace, this intervention also motivated employees to continue engaging in walking and improving their perceived productivity and changing their PA behaviour. This intervention contributes to the existing workplace PA, health, and wellbeing literature and more specifically, to the scarce research focused on university employees. Walking is beneficial for physical and mental health, and the increased steps evident in this intervention may have positively contributed to employee's health, and wellbeing. The present findings support previous research concluding that 10,000 steps challenge positively change behaviour and improve health and wellbeing in the workplace (24). Thus, employees recognising the benefits of walking during the working day may be the cause for the positive perceived influence on behaviour change. Despite motivation, competency, and behaviour change, employees suggested that they were willing to participate in the future workplace interventions if focused on PA, health, and wellbeing. Employees willingness to engage in a similar intervention in the future, increased steps, and overall positive experience testify the success and positive impact of this intervention. The participant university and extended working environments could adapt the approach of this intervention to plan same/similar interventions for promoting healthy and active lifestyle in the workplace for all employees in the future.

Data availability statement

The datasets generated and/or analysed during the current study are not publicly available due [to PhD research] but are available from the lead author on reasonable request.

Ethics statement

The studies involving humans were approved by Birmingham City University, Health, Education & Life Sciences Faculty Academic Ethics Committee. 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

AS: conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing – original draft preparation, visualization, and project administration. AS, MGZ, SD, MC, AK, and NW: writing – review and editing. MC, AK, and NW: supervision. All authors contributed to the article and approved the submitted version.

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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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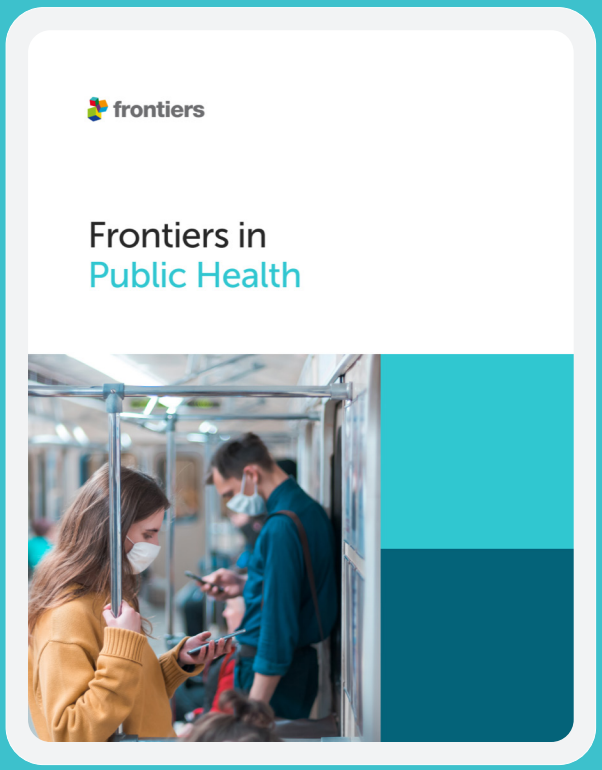

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