Quality of life improvement: Smart approaches for the working and aging populations

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Quality of life improvement: Smart approaches for the working and aging populations

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Editorial: Quality of life improvement: smart approaches for the working and aging populations

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Editorial on the Research Topic
Quality of life improvement: smart approaches for the working and aging populations

Introduction

Quality of life (QoL) is a notion that can be defined and treated in very complex manners depending on the context. It can be seen as a perception of a person's life and satisfaction and overall enjoyment with it, as well as its wellbeing, which depends on many diverse factors stemming from various domains such as health, psychological state, security and safety, beliefs and meaning, social position, environment conditions, relationships, economy position, etc. (1).

European Framework 8+1 (2) categorizes those factors affecting Quality of life in the following eight groups: (i) material living conditions—income, consumption, and material conditions; (ii) health—healthy and unhealthy behaviors, and access to healthcare; (iii) education—competences and skills, lifelong learning, and opportunities for education; (iv) productive and valued activities—working, volunteering, etc.; (v) governance and basic rights—institutions and public services, discrimination and equal opportunities, and active citizenship; (vi) leisure and social interactions—quantity and quality of leisure, as well as access to leisure, and the social dimension; (vii) natural and living environment—pollution, access to green and recreation spaces, as well as landscape and built environment; and (viii) economic and physical safety—wealth, debt, and income insecurity from the economic side, and crime and a perception of physical safety from the physical side. Lastly, it includes overall experience of life as an important influent as well.

Improving Quality of life as a multidimensional and complex concept should be a goal of research activities in general for all population groups (children, teenagers, young adults, parents, women, men, unemployed, employed, older adults, etc.). However, it is especially interesting to address it in terms of working and aging populations. Namely, demographic data suggests an increased need for workers worldwide and a rapid aging trend in the active workforce and in general also. This trend of workforce deficit and population aging will be even more prominent in the future (3). Statistics given by United Nations (4) say that by 2050 there will be 1.6 billion people aged 65 years or older (one in six people), while the

number of people aged 80 years or older is growing even faster. Also, as fertility levels fall, the share of young people declines, while the shares of working-age adults and older people go up.

Therefore, if one wants to remain concurrent in the upcoming challenging economic environment with lack of workforce, increased costs, labor supply chain reduction, or successfully cope with difficulties related to the needs of older adults and their caregivers and family members (such as lack of care force, finances, etc.), smart approaches need to be developed and utilized for improving the Quality of life for working and aging population groups. Those smart approaches include policies, methods, and practices, as well as technologies and solutions. For example, those smart approaches could cover the use of technology and innovation such as Internet of things (IoT), Web of things (WoT), Virtual reality (VR), Augmented reality (AR), Artificial intelligence (AI), etc. in products, services, solutions, and systems in public and private concept used to improve the Quality of life of older adults and working population which is aging. In addition, the application of new, creative, original, and inventive ideas to policies and strategies can domain-depending step-by-step improve the working conditions by supporting, for example, private-business life balance, adjusting tasks to age, etc. thereby improving the Quality of workers life and extending their working ability.

Smart approaches for Quality of life improvement of aging and working population

The Editorial aims to present the contributing articles of the Research Topic related to Smart Approaches for the Working and Aging Populations in terms of Quality of life Improvement. The Research Topic has published articles received from September 2022 to February 2023 regarding: (i) smart policies, methods, and practices, technologies, digital solutions, as well as security and privacy issues of technologies and solutions contributing to Quality of life; (ii) policies, methods, and practices, technologies and solutions, as well as security and privacy issues of technologies and solutions related to smart and healthy aging; (iii) policies, methods, and practices, technologies and solutions, as well as security and privacy issues of technologies and solutions related to smart and healthy working; and lastly (iv) artificial intelligence solutions related to Quality of life improvement, smart and healthy aging and working. These studies were conducted in countries worldwide which indicates that this topic is popular and contemporary in all corners of the world and it should be addressed by the research community more intensively.

The first group of articles refers to smart policies, methods, and practices, technologies, digital solutions, as well as security and privacy issues of technologies and solutions contributing to Quality of life. Four articles fit into this group presenting several technology solutions aimed at enhancing the Quality of life for older adults. Gambo et al. provided the review of current technological solutions designed for older adults, including the following aspects: work life, community engagement, and wellbeing at home. Although smart home technology holds promise in encouraging sustainable living, its adoption among older adults remains modest.

Wei et al. explored how intergenerational relationships impact the willingness of seniors to accept smart home services and found positive impact on empowering aging individuals to continue living independently by leveraging technology. As global unemployment rises, young generations are turning to the informal sector for employment opportunities, where the high risk of occupational hazards calls for effective healthcare. Therefore, Oladosu et al. identified existing factors affecting access to healthcare in order to clarify the pathways by which they may impact the health and Quality of life of young generations, providing insights to guide policy development. In similar study, Grakh et al. identified stressors and stress levels among veterinary students in order to assist in developing and implementing coping strategies to safeguard the mental health of students, contributing thereby to their Quality of life.

The second group of articles refers to policies, methods, and practices, technologies and solutions, as well as security and privacy issues of technologies and solutions related to smart and healthy aging. Nine articles can be classified into this group summarizing recent research on given topic. The conventional model of older adults care services faces challenges, including the outdated design of information platforms, subpar quality in caregiving, and issues related to the "digital divide." Consequently, Zhang and Xu proposed an enhancement in the quality of older adults care services through the implementation of a smart older adults care service model, rooted in grassroots medical and health care. Moreover, Wang and Zhu examined the importance of constructing public health informatization, with a specific emphasis on the components involved in such construction. Furthermore, Zhao et al. found that the smart medical system has the potential to offer significant convenience to both the older adults and community healthcare. In that sense, Rmadi et al. evaluated head-mounted display virtual reality tolerance among older nursing home residents through cybersickness and anxiety state. Abdulrazak et al. proposed approach utilizes unobtrusive IoT technology and algorithms for detecting change points to monitor the daily health status of older adults. Jiang and Liu studied how does the community- and home-based medical care service affect the social participation of the chronically ill older adults. Sun discussed an establishment of the emergency material reserve mechanism for public health emergencies and optimization of the management of various functional departments while proposing to strengthen management personnel allocation and optimize work processes. Additionally, Wang, Liu, Zheng, et al. concluded that comprehensive feedback mechanism for older adults can mitigate speculative practices by providers of older adults care services and platforms, and government can dynamically adjust penalties and subsidy policies. Finaly, when it comes to policies, Zhang, Ning et al. proposed three policy recommendations to promote the development of a new model of integration of sports and medicine in China.

The third group of articles includes seven studies and refers to policies, methods, and practices, technologies and solutions, as well as security and privacy issues of technologies and solutions related to smart and healthy working. In this context, Wang, Liu, Zhu, et al. made an investigation into enhancing the occupational safety and employment safeguards for takeout workers within the

framework of public health optimization. Kalski et al. focused on preventive health examinations in order to early identify health-related risk factors and maintain workability. Zhang, Zhang et al. explored the present condition of health insurance governance for full population coverage in China along with its influencing factors, and offered empirical insight that can be referenced by countries sharing similar social backgrounds with China. Furthermore, Qin et al. explored the influence of job satisfaction and sleep quality on the correlation between work stress and depression among Chinese healthcare workers, and whether the mediation models varied based on differences in educational degrees. Alif et al. identified a decline in disability-free survival among individuals engaged in "elementary" occupations, particularly those entailing elevated accident risks and unfavorable social climates. Chen et al. provided evidence supporting the idea that the combination of low wages and extended working hours constitutes notable occupational factors that have an adverse effect on the subjective sleep quality of female care workers from Southeast Asia employed in Taiwan. Lastly, Zhu et al. implemented tailored psychological adjustments and interventions with the aim to safeguard the mental wellbeing of civil servants, enhance their proficiency in addressing public emergencies, and empower them to apply accurate and positive psychological approaches when dealing with emergencies and high-pressure situations.

In the end, the fourth group of articles refers to artificial intelligence solutions related to Quality of life improvement, smart and healthy aging and working. In this sense, Gu et al. proposed the evaluation model of express service for addressing the shortcomings of the service industry and enhancing the quality of service.

Conclusion

Considering all of the above, this Editorial can provide the following conclusions. Although it covers research studies on policies, methods, and practices, technologies and digital solutions contributing to Quality of life, as well as smart and healthy aging and working, associated security and privacy issues are not sufficiently addressed. In addition, artificial intelligence solutions related to Quality of life improvement, smart and healthy aging and working remain unexplored. These issues can serve as a starting point for future research activities, as well as idea for launching new Research Topics.

Author contributions

SB: Writing – original draft, Writing – review & editing. ZA: Writing – original draft, Writing – review & editing. JBH: Writing – original draft, Writing – review & editing.

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Identification and assessment of stress and associated stressors among veterinary students in India using a cross-sectional questionnaire survey

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Background: Veterinary education, is a rigorous professional training program, which exposes students to significant academic and non-academic pressures. The identification of stressors and stress levels among veterinary students mighty help the designing and implementation of coping strategies to protect the students' mental health.

Methods: A 44-item based cross-sectional questionnaire survey was prepared and disseminated among veterinary students in India to identify the stressors responsible, measure the amount of stress, and relate stress to characteristics like gender, degree year, and family income. A total of $n = 611$ veterinary students across 14 states including 27 colleges/universities participated in the study. The collected data was evaluated for sampling adequacy, construct validity, and reliability using a set of statistical tests.

Results: The analysis revealed high sampling adequacy with a KMO value of 0.957 and a highly significant anti-image correlation ($p < 0.001$). The principal component analysis generated six factors or subscales which effectively explained 51.98% of the variance in the data, depicting high construct validity. The Cronbach's alpha value of 0.957 revealed high internal consistency for the questionnaire. Analysis revealed more than 94% of pupils under stress, with levels ranging from moderate to severe. Academic-related stressor (95.58%) was the leading cause of overall stress in the present study followed by inter- and intrapersonal and career related-stressors (93.12%) and exams and evaluation-related stressor (90.99%). In comparison to male students, female students reported significantly higher levels of overall stress, academic stress, and intrapersonal and interpersonal stress ($p < 0.001$) using Chi-square. The students from lower-income families experienced significantly higher overall stress as well as stress due to family responsibilities ($p < 0.001$). The first-year undergraduate students reported significantly higher ($p < 0.001$)

stress due to family responsibilities-related stressors whereas second-year students due to social activities-related stressors. The hierarchal regression model predicted that gender, family income, academic-related stressors, inter- and intrapersonal and career-related stressors, and social activities-related stressors can be employed to evaluate overall stress among students, as they ensured the maximum variance in the data ($p < 0.001$).

Conclusions: To the best of our knowledge, this is the first Indian study to identify stressors, quantify associated stress and predict major attributes to be targeted in future studies for veterinary students.

Introduction

Stress is a non-specific response of the body to the various events which enable individuals to perceive and cope with the adversities in both physical and social environments (1). The events leading to stress including personal and environment are considered stressors. The response of an individual to a stressful stimulus may be complex and is generally attributed to various factors *viz.*, socio-cultural, psychological, physical, environmental as well as individual perception (2).

Veterinary education is a rigorous professional degree program with a heavy workload that demands significant personal time (3). Although challenges are part of every professional curriculum and the subsequent phases of life transition, veterinary education has its pattern of situations that may cause students to feel tense and overwhelmed (4). For instance, the persistent comparison with medical counterparts within initial days of admission, maintenance of good academic scores for fellowship, lower stipend for internships and conflicts with animal owners, etc. are more frequent events for veterinary students in India. This challenging environment poses a serious concern for the mental well-being of veterinary students and needs to be addressed in terms of impact, prevalence, and management (5). Academic stressors are majorly responsible for adverse outcomes such as mental outbursts, stress, depression, and anxiety among veterinary as well as medical students (6). The heavy workload, lack of clinical skills, concerns of being compared with peers, lack of time for studies, and recreational activities and ignorant administration are some of the frequently reported sub-factors under academic stressors leading to stress among veterinary students (4, 7). A comparative study by Yang et al. (8) in Australia reported higher overall stress among veterinary students as compared to medical students.

Other than academic stressors veterinary students are also equally prone to non-academic stressors, including family issues or relationships, personal health concerns, and financial problems (7). These stressors may pave the way to mental health problems such as debilitating stress, anxiety, and depression among students, in absence of coping strategies (6, 9). The inter- and intrapersonal and professional interactions as well as conflicts between animal and human interests also predispose veterinary students to mental stress (2, 10). These conflicts may arise due to the owners' perception of lack of effect after treatment, non-cooperation of owner in the restraining of their pet/animal, and pressure on students for treatment using influential position (11). The lack of career opportunities along with insulting remarks by politicians in recent times in India may add to the list of stressors veterinary students are subjected to (12). Additionally, students in the pre-clinical and clinical year of graduation and postgraduate (PG) students involved in clinical practice at university/college clinics are more likely to experience emotional aspects while dealing with various aspects of the death of the animals, managing challenging clients (angry or non-cooperative), concerns over lack of time for recreation, and mistakes in diagnosis (2). These practice-related events may impart a long-term mental impact on veterinary students leading to other unfortunate consequences like suicidal tendencies (13).

The stress experienced at the graduation level may expand into the professional lives of veterinarians as practitioners and academicians leading to mental health consequences that might affect the quality of life and reduces the socioeconomic productivity (5). The norms, beliefs and behavior of a professional expressed in life are influenced by student life experiences during their professional education (14). There is thus a need to provide such an atmosphere that teach and suggests practical approaches for enhanced resilience in response to stress.

A manageable level of stress for a sensible duration may however serve as an important stimulant to meet life's challenges but chronic stress can have serious consequences on the emotional, psychological, and physical health of an individual (15). Several studies concerning various stressors and associated stress among veterinary students have surfaced in recent times worldwide, but unfortunately, similar efforts are still lacking in Asian countries including India. Although a

few studies describing the mental health issues among medical students in India (16) have been conducted but the veterinary counterparts were completely ignored as there is not a single study investigating the issue among veterinary students.

The detection of stress and associated stressors at early stage might help in reducing the risk of psychosocial and behavioral problems, such as violence, suicidal thoughts, and use of drugs and alcohol as coping method (17, 18). It will also help in developing coping strategies or approaches to reduce or eliminate the most daunting stressors and thus assurance of quality life for the individual. Therefore, this study aimed to develop and validate a new survey instrument to identify the stress and associated stressors among veterinary students in India and to determine relationship of stress with other variables *viz.*, gender, income, and degree year. The study further aimed to provide the veterinary students with a validated self-reporting tool to assess the level of stress they are subjected to and to seek help accordingly. Findings of current study are expected to provide a base study to attract the attention of health planners and veterinary institutes administrations to develop sufficient stress coping programs. The findings will provide most important and frequent stressors to be targeted to reduce the overall stress to the veterinary students in India. Based on literature search and to the best of our knowledge, this is the first Indian study of its kind.

Materials and methods

Study design

The students enrolled in various veterinary universities/colleges of India in undergraduate (UG); Bachelor of Veterinary Sciences and Animal Husbandry (BVSc & AH), post-graduate (PG); Master of Veterinary Sciences (MVSc), and Doctor of Philosophy (Ph.D.) degree courses at the time of the study were included in the survey. The students who have already completed 6 months or more in the veterinary curriculum were included and the students already graduated were excluded from the survey to avoid confounding bias. Participation in the study was voluntary, and written consent was obtained from all the participants in the study. The sample size was calculated using the "Raosoft calculator" (http://www.raosoft.com/samplesize.html?nosurvey). The sample size of 377 was estimated based on a 50% response distribution, a 5% margin of error, and a 95% confidence interval. The expected response proportion of 50% was assumed as there was no such study earlier.

Sampling and procedure

A total of 1,000 questionnaires were to be sent to students of different veterinary institutes in India through emails and/or personal contacts and social media groups. For this purpose, an academician (teacher/researcher) or post graduate students (known to researchers) from each veterinary institute of India was contacted and was requested to share the questionnaire pdf file with students of their respective institute (snowball sampling). The questionnaire pdf file included a consent form and a link to the online interface of Google Forms (Google LLC, Mountain View, CA, USA). The survey remained open for 3 months from July 2021–September 2021.

Survey instrument

For the present study, a cross-sectional questionnaire was designed with 50 items initially. After formal testing on 20 undergraduate (UG) students, six items were removed due to irrelevant and controversial nature (admission quota, caste, worst incidents of academic life and abuse by teachers, etc.), leading to a final set of 44 closed items (Supplementary Table 1). The items were organized into six categories *viz.*, academic-related stressors (ARS), inter or intrapersonal, and career-related stressors (IPCRS), teaching and learning-related stressors (TLRS), exams and evaluation-related stressors (EERS), social activities related-stressors (SARS) and family responsibilities related stressors (FRS), based on the extensive review of related veterinary and medical literature (16, 19, 20). The first section of the questionnaire collected socio-demographic data of students specifically gender, age, religion, family income, degree year, state of residence, and name of the currently enrolled college/university. The second section included questions based on rating the intensity of stress caused by each item on a Likert scale of 0 (causing no stress) to 4 (causing extreme stress) (21). For example, "How much stress heavy workload causes to you?" with a response option on the scale (0-no stress at all; 1-causes mild stress; 2-causes moderate stress; 3- causes high stress; 4-causes severe stress). The items were placed in random order to avoid the carryover effect of responses. The survey instrument was designed to take 10–15 min to complete. The scoring of values for quantification of stress level was done by obtaining the mean values for each of the categories/subscales and the scores were rated as no or mild stress (0.00–1.00), moderate (1.01–2.00), high (2.01–3.00), and severe (3.01–4.00) as described by Jayarajah et al. (20). The overall stress was calculated by taking the mean of the overall score of each category.

Data analysis

The completed questionnaires were manually checked for data quality and codes were assigned to responses in Microsoft® Office Excel 2010 for statistical analysis. The statistical analysis was performed using the Statistical Package for Social Science (SPSS) v. 20. The questionnaire items were analyzed for validity, reliability, association between the variables, and

TABLE 1 Socio-demographic characteristics of the participants (*n* = 611).

Characteristics	*M* (SD)	*n* (%)
Age (in years)	23.2 (2.8)	
Gender		
Male		388 (63.50)
Female		223 (36.50)
Religion		
Hindu		558 (91.32)
Muslim		19 (3.10)
Christian		13 (2.12)
Buddhist		10 (1.63)
Sikh		7 (1.14)
Others		4 (0.65)
Veterinary degree year		
BVSc and AH 1st year		59 (9.65)
BVSc and AH 2nd year		80 (13.09)
BVSc and AH 3rd year		98 (16.04)
BVSc and AH 4th year		78 (12.76)
BVSc and AH 5th year		95 (15.55)
MVSc		167 (27.33)
Ph.D.		34 (5.56)
Family income		
Below 2 lakhs		247 (40.42)
2–5 lakhs		191 (31.27)
More than 5 lakhs		173 (28.31)

M, Mean; SD, Standard Deviation.

FIGURE 1
Scree plot showing Eigenvalue of the factors generated.
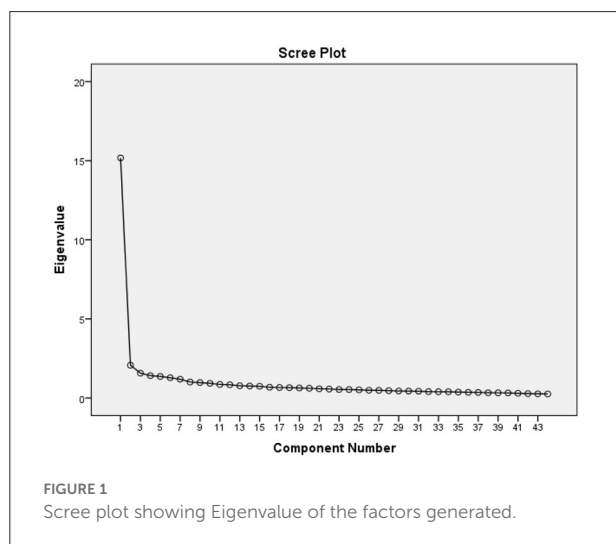
regression modeling. The questionnaire utilized exploratory factor analysis to determine whether new factors (subscales) could be created and to examine the structure of the relationship between questionnaire items. The principal component analysis (PCA) with Promax rotation and scree plot was used to extract the factors with an Eigenvalue of more than one. The correlation analysis was used to examine the independence of the new factors as a measure of construct validity. The internal consistency and reliability of the questionnaire, factors, and items were measured using Cronbach's alpha ([22]). The level of stress along various domains such as gender, income, professional degree year, and age was analyzed using the Chi-square test. The correlation matrix was run to study the inter-item correlations of all factors as well as non-demographic variables. The anti-image correlation, the Kaiser–Meyer–Olkin (KMO) test, and Bartlett's test of sphericity were used to determine the sampling adequacy and to assess the factorability of the correlation matrix. To justify factor analysis Bartlett's test should be significant and KMO values should exceed 0.60 ([23]). A series of hierarchical regression analysis were conducted to investigate which stressors significantly predicted the overall stress among the students. For hierarchical analysis, the categorical variables were provided with dummy codes (for example, dummy coding for male = 1 and female = 2). The variables that either yielded significant association or were hypothesized to be associated with stress were used in regression analysis. The gender was entered in step 1, degree year in step 2, family income in step 3, and the six stressors (ARS, IPCRS, TLRS, EERS, SARS, and FRS) were added in step 4. Only a single dependent variable (i.e., overall stress) was used.

Ethical considerations

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their well-informed written consent to participate in the study.

Results

A total of 611 veterinary students of India from 14 states covering 27 colleges/universities provided their consent to participate in the study, with a response rate of 61.1%. Table 1 concludes the participants' demographic breakdown. The mean age of respondents was 23.2 ± 2.8 years old with the majority identified as male (63.6%) respondents. A total of 247 (40.4%) students had family income below two lakhs. The majority of the participating students (67.10%) were from undergraduate (BVSc and AH) degree years, followed by MVSc students (27.33%) and Ph.D. students (5.57%).

TABLE 2 Loading of variables on factor from the Promax rotation matrix.

Item label under factors		Factor loadings	Communalities*	Cronbach's alpha if an item deleted
ARS	Rude behavior of college staff	0.785	0.572	0.882
	Ignorance of problems by the administration	0.760	0.567	0.882
	Lack of teaching skills of teachers	0.750	0.553	0.882
	Biasness/favors of teachers for selected students	0.644	0.451	0.885
	Lack of guidance regarding future jobs	0.607	0.589	0.883
	Perception of a gap in learning and practice	0.520	0.565	0.880
	Conflicts with animal owners and activists	0.487	0.458	0.886
	Lack of professional skills	0.449	0.565	0.883
	Perception of leniency in evaluations in other colleges	0.436	0.459	0.889
	Deviation of actual protocols in treatment by teachers	0.423	0.451	0.886
	Lack of guidance from teachers in the study	0.357	0.518	0.884
	Not enough study material	0.308	0.503	0.883
	Conflicts with other students	0.356	0.381	0.891
	Verbal/physical abuse by other students	0.318	0.516	0.889
IPCRS	Perception of failure to establish a career	0.767	0.614	0.848
	Unable to answer questions from pet owners	0.635	0.558	0.853
	Fear of getting poor marks	0.625	0.655	0.846
	Facing the death of an animal at clinics	0.599	0.408	0.865
	Lack of time for revision of content	0.573	0.607	0.851
	Need to do well (by others)	0.481	0.527	0.852
	Self-expectation to do well	0.474	0.464	0.860
	Preparing competitive exams	0.445	0.410	0.861
	Difficulty in understanding content/course	0.337	0.531	0.852
TLRS	Lack of recognition/praise for your work	0.657	0.536	0.828
	Frequent interruption of work by others	0.619	0.500	0.827
	Stress while working with computers	0.609	0.549	0.838
	Difficulty in finding a person to talk to	0.568	0.550	0.825
	No feedback by teachers	0.564	0.547	0.821
	Conflict with teachers	0.551	0.511	0.821
	Unable to answer in class	0.431	0.599	0.822
	Lack of communication among teachers	0.412	0.570	0.824
	Self-Unwillingness to study veterinary science	0.318	0.342	0.839
EERS	The stress of examination or tests/viva	0.848	0.615	0.782
	Frequent examinations	0.697	0.591	0.779
	Heavy workload	0.663	0.567	0.770
	The stress of class presentation/discussion	0.620	0.545	0.802
	Falling behind in study schedule	0.450	0.557	0.779
	Inappropriate assignments by teachers	0.402	0.530	0.791
SARS	Talking to animal owner's history taking	0.722	0.584	0.578
	Fear of clinical practice (injection/surgery)	0.473	0.491	0.604
	Parental wish to study another field/profession	0.399	0.376	0.638
	Lack of time for family and friends	0.354	0.403	0.595
FRS	Financial problems (family debt)	0.637	0.536	0.592
	Family responsibilities/expectations	0.585	0.526	0.593

*Communalities are estimates of variance accounted for by each variable in the factor solution.

Sampling adequacy and construct validity

The KMO value for the current questionnaire was 0.957 which indicated very high sampling adequacy. Bartlett's test of sphericity was also found highly significant (chi-square = 1,222, $p < 0.001$) which again indicated that factor analysis might be useful with the current study data. The exploratory factor analysis was used to determine the construct validity of the questionnaire. The total numbers of components were extracted using PCA and Promax rotation (oblique rotation). The initial exploratory factor analysis resulted in the extraction of eight factors with Eigenvalue >1 (Figure 1) that collectively explained 56.98% of the overall variance of the data. As two out of the eight factors comprised only two items and there was shared variance between factors, items were forced to a six-factor reduction, with suppression of coefficients below 0.30. The six-factor reduction explained 51.98% of the total variance. The loading of each item to the new factors was based on the factor loading and our construct as in the method section. The factor structure along with communalities and internal consistency of each item along with factors were detailed in Table 2. The items were reshuffled to each category as loaded by the factor analysis. In this study, the scores of the items within each subscale were summed, and the mean score of each subscale was used to represent the stress level of the students in six already designed categories: *viz.*, ARS, IPCRS, TLRS, EERS, SARS, and FRS.

Reliability analysis

The questionnaire showed high internal consistency indicated by Cronbach's alpha value of 0.957 which lies in an excellent grade. Moreover, Cronbach's alpha values of individual subscales ranged from 0.647 to 0.892, indicating good internal consistency (Table 3). When individual items were removed, Cronbach's, alpha ranged from 0.578 to 0.889 indicating that all the items contributed to the adequacy of the scale (Table 2). Additionally, an anti-image correlation with individual items also confirmed the sampling adequacy ($p < 0.001$) for further analysis.

Correlation analysis

Inter-factor correlations, as well as correlations of factors with other variables of the questionnaire (gender, income, and degree year), were examined using bivariate variation (Spearman's rho) as shown in Table 4. Inter-factor correlations ranged between 0.006 and 0.608, which indicates generally acceptable independence. The highest correlation between ARS and IPCRS (0.608) indicates some overlap between these two factors. All the factors, except IPCRS, had a higher discriminant ability and were statistically significant ($p < 0.05$). All the

TABLE 3 Questionnaire factors with mean score and reliability estimates (Cronbach's alpha).

Factor	Number of items	Mean (SD)	Cronbach's alpha
ARS	14	2.88 (0.79)	0.892
IPCRS	9	2.82 (0.86)	0.868
TLRS	9	2.46 (0.89)	0.843
EERS	6	2.64 (0.86)	0.813
SARS	4	1.95 (0.84)	0.670
FRS	2	2.54 (1.05)	0.647

factors were significantly correlated with overall stress except for FRS, and TLRS, and these two seem to have a lower discriminant ability to measure overall stress than other factors. The correlation between factors and other variables varied from 0.006 to 0.280. ARS and overall stress were significantly correlated to gender and income but not to degree year. The inter-item total correlation value was more than 0.3 for 20 items. The rest of the items, however, had a lower but statistically significant correlation and there was no considerable change in Cronbach's alpha with the deletion of any item, which indicates acceptable reliability. Therefore, all 44 items were included in the questionnaire. The Cronbach's alpha value of each stressor group was depicted in Table 3 and Cronbach's alpha value if the scale item was deleted for an individual item in Table 2.

Characterization of stress and its relation with other variables

All the students reported some degree of overall stress. The students with a mean score of more than 1.0 i.e., those who reported scores in the moderate, high, and severe categories were considered under stress. Overall, for 611 students, 94.10% (575) were under stress (mean score of more than 1.0), of which 40.3% (232) reported moderate level of stress, 47.5% (273) reported high stress and 12.2% (70) students reported the level of stress as severe. Overall among the stressed 59.65% (343/575) students had high to severe stress. The most important stressors group among veterinary students was ARS (95.58%) followed by IPCRS (93.12%), EERS (90.99%), TLRS (87.72%), FRS (79.54%) and SARS (66.12%) as shown in Table 5. In summary, Table 6 showed that female students significantly experienced more overall stress with ARS and IPCRS being the major contributing stressors as compared to the male students. The students with lower family income (less than two lakhs per annum) experienced significantly higher overall stress as compared to students with higher family income. The students of the BVSc and AH second year reported SARS as a significant stressor whereas first-year students responded FRS as a major stressor.

TABLE 4 Correlation analysis of main variables (N = 611).

		1	2	3	4	5	6	7	8	9	10
1.	ARS	–	0.608**	−0.006	−0.093*	−0.011	0.018	0.701**	0.220**	−0.081*	0.063
2.	IPCRS		–	0.018	−0.010	−0.070	0.054	0.748**	0.280**	−0.008	−0.049
3.	TLRS			–	0.531**	0.500**	0.532**	−0.022	0.057	−0.047	−0.079*
4.	EERS				–	0.488**	0.368**	−0.083*	−0.010	−0.035	−0.069
5.	SARS					–	0.358**	−0.098*	−0.043	−0.130**	−0.068
6.	FRS						–	0.034	0.016	−0.114**	−0.098*
7.	Overall Stress							–	0.172**	−0.141**	−0.006
8.	Gender								–	0.197**	0.204**
9.	Income									–	0.155**
10.	Year										–

*p < 0.05.
**p < 0.01.

TABLE 5 Proportion of students who indicated stress related to specific factor*.

Factors	n (%)
ARS	584 (95.58)
IPCRS	569 (93.12)
EERS	556 (90.99)
TLRS	536 (87.72)
FRS	486 (79.54)
SARS	404 (66.12)

*N = 61, Mean score more than 1.0.

Hierarchical regression analyses

The results of the hierarchical regression analysis indicated that in step 1, gender positively predicted and accounted for 3% of the variance ($p < 0.001$). In step 2, the degree year was not significant. In step 3, the family income negatively predicted and accounted for 6% of the variance ($p < 0.001$). In step 4, the six stressors significantly accounted for an additional 68% of the variance ($p < 0.001$), with only ARS, IPCRS significantly predicting the overall stress (Table 7).

To summarize, female students had a higher level of overall stress than male students. The students with lower family income have reported high overall stress and the students who reported high levels of ARS, IPCRS, and SARS, were more likely to be included in the high overall stress category.

Discussion

The current study yielded six factors using principal factor analysis. All the six factors generated showed good internal consistency and explained the adequate cumulative variance in the data. Overall, of the 611 students, 575 (94.10%) were

under stress. The more number of students under high to severe stress category in the current study is a serious concern. The moderate level of stress responded by students, might be necessary and manageable to provide motivation and increased productivity (24). Evidences suggest that a moderate level of stress strengthens the connection between neurons in the brain, leading to the improvement in attention span, and memory, and thus enhanced productivity (15, 25). On the other hand, high and severe stress can be detrimental to the physical and mental health of individuals leading to adverse consequences such as depression, anxiety, and suicidal thoughts (26). The current study reported ARS as a major contributor to overall stress with a maximum of 95.58% of students citing academic problems as major stressors. Williams et al. (2), observed that more than 85% of veterinary students experienced academic-related stress, including academic and practical workload, which is in line with several other studies in various countries (10, 27, 28) including the current study. Another study by Gupta et al. (16) among medical students in Kolkata, India reported that 91.1% of medical students experienced stress, and academic-related stressors were identified as a major source of stress for 94.9% of students, which is in consensuses with our findings. The academic stressors mainly included heavy workload, rude behavior of college staff, ignorance, and biases by college/university administration. Although heavy workload may also be regulated and a course work with reduced burden can be designed or implemented but the factors such as rude behavior of non-teaching staff and ignorance of genuine student problems by the administration are more serious issues as they fulminate within the wall of the institutes and easier to resolve. In the present study, female veterinary students experienced significantly higher overall stress, and ARS and IPCRS related stress as compared to male students. The similar patterns of stress among female students as compared to male counterparts are reported in various studies around the globe (6, 29–31). A set of conditions such as depression, chronic pain, stress, and

TABLE 6 Significant relation of gender, family income, and degree year with overall stress and individual factors.

Variables		Frequency, n (%)	p-value (Chi-square)
Gender			
Overall stress	Male (389)	356 (91.51)	<0.001
	Female (222)	219 (98.64)	
ARS	Male (389)	363 (93.31)	<0.001
	Female (222)	221 (99.54)	
IPCRS	Male (389)	350 (89.97)	<0.001
	Female (222)	219 (98.68)	
Income			
Overall stress	Below 2 lakhs (247)	234 (94.73)	<0.001
	2–5 lakhs (191)	179 (93.71)	
	More than 5 lakhs (173)	162 (93.64)	
FRS	Below 2 lakhs (247)	208 (84.21)	<0.001
	2–5 lakhs (191)	142 (74.34)	
	More than 5 lakhs (173)	136 (78.61)	
Degree year			
SARS	First-year (59)	31 (52.54)	<0.005
	Second-year (80)	65 (81.25)	
	Third-year (98)	69 (70.40)	
	Fourth-year (78)	52 (66.66)	
	Final Year (95)	69 (68.42)	
	MVSc (167)	95 (56.88)	
	Ph.D. (34)	23 (67.64)	
FRS	First-year (59)	59 (100)	<0.001
	Second-year (80)	70 (87.50)	
	Third-year (98)	88 (89.79)	
	Fourth-year (78)	54 (69.23)	
	Final Year (95)	73 (76.84)	
	MVSc (167)	121 (72.45)	
	Ph.D. (34)	21 (61.76)	

anxiety disorders are more frequent among females (32, 33) and this may be partly attributed to the effects of sex hormones as some of these gender differences emerge during reproductive years and generally diminish with age or after menopause (34). Additionally, literature describes ruminative thinking as more frequent in females which increase the risk of stress and depression (35). The academic performance of female students in developing countries like India plays a decisive role in higher education and career, which might create pressure additional to regular convincing for getting married by parents which might affect their academics and other activities, and this can be the reason for high academic, inter or intrapersonal and conflict-related stress and overall stress (36). Although every stressors needs attention to safeguard the mental health of female students

but it further needs investigations to know how the academic stressors are affecting the female students and the strategies to check the same.

The students with lower family income (male and female) had reported significantly higher overall stress as well as stress due to FRS, which might be attributed to additional family responsibilities and fear of failure to fulfill future expectations. Moreover, factors such as limited access to resources to alleviate stress, experiencing frequent financial distress, and unmet material needs and necessities such as food and clothing may predispose such students to stress (37). The lower-middle-class family students also reported higher stress due to teaching and learning-related stressors, social activities-related stressors and exams, and evaluation-related stressors when compared with the students of the upper class or high-income families. The uncertainty of future career opportunities and lack of funds to continue the education might be the factors leading to stress in such students. Huge amount of tuition fee, low-skill generation and failure to provide with job opportunities by various veterinary universities/institutes in India charge further deepens the level of stress faced by the financially weaker section of students.

The IPCRS-related stress was second most reported in the current study followed by ARS. The factors such as perception of failure to establish a career, fear of getting poor marks, and fear of facing the death of an animal were the major contributors to the IPCRS-related stress among veterinary students in India. Similar findings were reported by Williams et al. (2); where self-expectations and emotional distress while facing animal death were the major contributors to the stress among veterinary students. The perception of failure to establish a career after graduation needs attention of the institutes as graduating students needs to be guided of the opportunities and skill set to be generated during their academics. For the TLRS-related stress, lack of recognition for your work, frequent interruption by others, and computer working-related stress were major contributors. The study conducted by Singh et al. (38) among veterinary students of Punjab, India however contradicts the findings of computer related-stress, where very low respondents reported computer-related distress or anxiety. But the lack of recognition for work and frequent interruptions at the college/university might certainly lead to stress (39). Among the EERS-related stress, frequent examination, heavy workload, and viva or practical evaluation were major factors leading to stress. However, some anxiety or stress before viva voce examination is a natural but heavy workload and frequent examination might be reduced to ease such stress. Nahm and Chun (25) also reported frequent examinations as one of the important stressors to be addressed for the veterinary students. The theory and practical examination can be made more flexible in terms of the number of questions and type of questions asked, mainly by reducing the lengthy questions and including more of objective questions. For SARS-related stress the factors *viz.*,

TABLE 7 Hierarchical regression of independent variables on overall stress among veterinary students.

Variable	B	SE B	Beta	Sig.	R^2	Adjusted R^2	ΔR^2	F change in R^2
Step 1								
Gender	0.28	0.06	0.17[¶]	0.000	0.03	0.03	0.03	20.00[¶]
Step 2								
Degree Year	−0.01	0.01	−0.02	0.470	0.03	0.02	0.00	0.52
Step 3								
Income	−0.17	0.03	−0.18[¶]	0.000	0.06	0.06	0.03	20.78[¶]
Step 4								
ARS	0.36	0.02	0.37[¶]	0.000	0.68	0.68	0.62	201.05[¶]
IPCRS	0.46	0.02	0.52[¶]	0.000				
TLRS	0.02	0.02	0.02	0.405				
EERS	−0.01	0.02	−0.01	0.526				
SARS	−0.06	0.02	−0.07[ж]	0.008				
FRS	0.00	0.02	0.01	0.667				

*N = 611.
[¶]p < 0.001.
[ж]p < 0.01.

history taking for a case presented in clinical complex, and fear of clinical practice were major contributors to stress and these factors were more significant for students in the pre-final year of the professional degree. These factors however can be mastered easily with regular practice and guidance from the professors and colleagues and of lesser concerns from the stress point of view.

On the construct and validity point, the three stressor categories of the questionnaire *viz.*, ARS, IPCRS, and SARS positively predicted the overall stress ($p < 0.01$), where ARS and IPCRS were highly correlated with overall stress using correlation analysis. Other variables such as gender and family income also predicted the variance within overall stress. The hierarchical regression analysis revealed that academics, inter or intrapersonal and career-related, and social activities-related stress positively predicted the overall stress for veterinary students in India. These findings can help the authorities to emphasize these factors to design coping strategies for stress management among veterinary students in India. Additionally, future studies can target only these limited categories to shorten the tool and time for quantification of the stress among students. The construct designed and validated in this study can be used effectively with high consistency to measure the stress level among veterinary students in veterinary colleges or universities across India. Veterinary students can self-evaluate their level of stress using this instrument, which might help them to seek early interventions.

It is evident from the findings of current and other studies that a high percentage of veterinary students are feeling stressed to a level that might impact their quality of life. One of the simplest solution to stress among veterinary students is stress-management training or instructing anxiety-reducing strategies to students every year or on regular basis. These may be implemented utilizing counselors, psychiatrists, or even outreach programs within the student body (40, 41). Evidence suggests that utilization of mindfulness based programs and encouraging a growth mindset, in place of a fixed mindset might help veterinary students to handle stressful events (42). Although the strategies above seem promising, literature also provides evidence that veterinary students might not utilize the counseling and medical attention for mental health issues, subjected to a negative stigma associated with such issues (43). Further, researchers have recommended various socio-behavioral models for promoting behavior changes among students, of which the most recently proposed theoretical model; Multi-Theory Model of Health Behavior Change (MTM) by Sharma (44) incorporates multiple socio-behavioral theories, into a model of two components— initiation and sustenance of health behavior change. This model has been used already by various researcher for the prediction of initiation and sustenance of health and stress management behavior changes such as a reduction in binge-drinking, increase in eating fruits and vegetables, improvement in sleep behaviors, increased physical activity, portion size control and participation in conscious relaxation behaviors (5, 45, 46). The MTM might be employed for predicting initiation and sustenance of health behavior change as it is both specific for health education and sustainable for long-term change. Another study found that a life coach for first-year medical students helped in the improved mental health of the students (47), which might be utilized by veterinary institutes to promote an intervention targeting behavioral confidence.

The professional faculty in veterinary institutes has a responsibility to support students during their education and to prepare them for all aspects of professional life and they can help address this problem by educating with appropriate knowledge, fostering the development of necessary skills, and providing guidance and empathetic support when needed (27). The administration needs to be more accessible and empathetic toward students' problems rather than ignoring them. As much of the stress reported in the study arises from academic-related stressors including heavy workload and intensive curriculum, there is an urgent need to introduce some newer changes to design a more apt and less stressful curriculum. The inclusion of workshops and meditation programs in the veterinary curriculum for stress management might serve as a guiding tool to balance life and raise awareness of individual needs (27). The cultural activities, sports activities, and sessions as workshops seeking feedback from the students from time to time might help to create a culture of inclusion, support, and acceptance.

Based on his study, Siqueira Drake (48) suggests the promotion of therapeutic or skill development groups to provide the students a platform to discuss their issues or to gather some skills, where potential topics to discuss may be time management, stress coping strategies, managing personal and professional relationships, and communication skills. These interventions thus might help by creating a supportive environment for students, where they can feel comfortable to seek the help if needed.

The administration may contribute by changing the atmosphere within the institute by arranging events, during the first degree year and beyond, in such a way to better connect students with support staff, teachers, and one another. Researchers across the globe consider that college administrators and faculty should create a safe, non-threatening environment to use resources such as counseling for mental-health concerns (49). To the best of our knowledge, this is the first study designed and validated to map out the stress among veterinary students in India.

Future directions and implications

Future investigations should be focused on identification of specific mental-health issues during the course of veterinary education. The other parameters such as depression and anxiety should also be evaluated to find any correlation with overall stress and other factors. As a higher number of students reported high to severe stress the future investigations should evaluate the coping strategies being used by these students and whether the strategies are adequate or leading to any maladaptive outcomes. Regarding educational interventions, subject or topic wise investigations need to be undertaken so as to identify the most difficult subjects for students and thus change in the content and timing can be implemented. Once these investigations yield

outcomes they must be shared with authorities responsible or university managers to implement the coping strategies or programs. As the mental health nowadays is being assessed from a broader perspective, the results will surely demand the call for educational interventions which consequently will ensure improved health and life for the veterinary students.

Limitation of the study

The low response rate from some of the veterinary colleges seems to limit the more accurate results, which could be obtained by involving every veterinary college/university in India. Further, the study was based on a single parameter of stress and other components such as anxiety and depression might be included in further studies. However, specific area selection bias can be there in the study, but sampling adequacy analysis and the first insight nature of the study might overcome that. Moreover, social desirability bias cannot be ignored but providing a real name was kept optional to reduce such bias.

Conclusion

High overall stress among veterinary students of India is a serious concern and most of this stress is due to various academic stressors which fulminate within the parameter of veterinary colleges/universities' campuses and classrooms. There is thus an urgent need to address such issues and design coping strategies to minimize the stress among veterinary students. This study can be taken as a basis for further evaluation of stressors and the levels of stress among veterinary students in India. This study also showed that this construct with six factors had acceptable psychometric properties and is a valid and reliable instrument that can be used in local settings for the assessment of stress among veterinary students.

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

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

Conceptualization: KG, VJ, DP, and RK. Methodology: KG, DP, and VJ. Formal analysis and investigation: KG, YB, DY, LS, NC, and KK. Writing—original draft preparation: KG. Writing—review and editing: KG, VJ, DY, and KK. Supervision: RK and VJ. 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. 2022.1059610/full#supplementary-material

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Research on express service defect evaluation based on semantic network diagram and SERVQUAL model

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This paper constructs a defect evaluation model of express service, uses the text mining methods of web crawler, SVM (Support Vector Machine) emotion analysis and LDA (Linear Discriminant Analysis) topic model to capture and clean up the online negative comment data of express service, establishes a semantic network diagram, and uses LDA topic model to extract the characteristic words of defect topic. Based on SERVQUAL model, it can classify the subject characteristic words of express service defects from the dimensions of tangibility, reliability, responsiveness, assurance, empathy and economy, etc., calculate the degree value and attention value of express service defects, and establish IPA model for defect mapping and identify the improvement direction. The evaluation model constructed in this paper has reference value for evaluating the defects of service industry and improving service quality. It is found that the "responsiveness" defect is the primary improvement direction, and the reliability, assurance and economy are the secondary improvement defects. Among them, the "responsiveness" defect has five improvement detail defects. The evaluation model constructed in this paper has reference value for evaluating the defects of service industry and improving service quality.

Introduction

In the context of e-commerce, express delivery has become an essential service. At the same time, the emergence of many express logistics enterprises makes enterprises begin to pay attention to the improvement of service quality (1). The level of express service has a significant impact on the satisfaction of e-commerce customers (2). However, at present, the relevant research on express service quality mostly focuses on the establishment of express service quality evaluation model and the main factors affecting express service quality (3–5), and there is little direct research on express service defects. Identifying and monitoring service defects is very important for enterprises to meet customer needs and improve service quality (6, 7). User generated content (UGC) has good autonomy, universality and interactivity, and can truly reflect user evaluation (8).

Text mining technology can transform the text content in UGC into the latest and valuable information (9–11). Semantic network diagram is a tool for text mining, which can be applied to the qualitative evaluation of express service quality (12, 13). SERVQUAL model is a quantitative evaluation tool, which not only measures the quality of service provision, but also shows users' views on the services provided (14, 15). This paper uses text mining method to build an express service defect evaluation model based on semantic network diagram SERVQUAL model, which helps the express industry identify the key elements that need to be improved in order to improve the service quality.

Literature review

Defects of express service

Service defects arise when the service level provided by enterprises is lower than customers' expectations (16, 17). Frequent express service failures will not only lead to the business loss and reputation damage of express companies, but also cause customers' emotional anxiety and have a negative impact on their satisfaction, resulting in negative word-of-mouth and complaints. For example, the uneven distribution of resources in Postal Express outlets affects the distribution efficiency and causes timeliness defects (18); Express service often has defects of convenience and trust (19); Accuracy and timeliness greatly affect the quality of express service (5); Delivery time and accuracy are the biggest obstacles in the delivery chain (20). Diversified problems or complaints from customers include relatively high distribution price, unreasonable signing process, timeliness of distribution, delayed delivery, damage and loss of goods, signing before inspection, etc. (21, 22); Even staff professionalism and uniform dress (23).

Most of the above studies use second-hand data obtained by questionnaire to identify quality defects, and lack first-hand data support from the perspective of customer perception.

Text mining and its application

Web text mining is the representation, feature extraction, content summary, classification, clustering, association analysis, semantic analysis and trend prediction of online text content (24). Text mining helps people make appropriate decisions by applying different artificial intelligence algorithms (25).

Using text mining technology, we can identify quality defects by obtaining the public feeling data of the network platform. For example, text mining technology can extract the basic mode of e-commerce logistics from a large number of unstructured documents and formulate the strategy of e-commerce logistics management (26). The poor efficiency of port logistics process can also be estimated by combining data-driven technology—process mining (PM), social network analysis (SNA) and text

mining (27). Text mining technology is used to identify cross-border logistics service elements and customers' feelings (28), and LDA model can also be used to identify service attributes (29). When studying the logistics service of fresh e-commerce, scholars also use text mining model based on convolution neural network to analyze the logistics service elements related to customer satisfaction (30). In the identification of key problems of service quality, scholars try to use text mining technology to analyze the medium and poor evaluation data in the online customer review data of e-commerce platform, and explore the prominent problems in logistics (31); Or analyze the negative network reputation of household products and services with the help of text mining technology to identify the key factors leading to logistics service errors (32); Or use SVM method to classify and analyze the positive and negative emotions of customer comments of express service (33, 34).

When identifying defects, the above studies mostly define them by the frequency of problems mentioned in the evaluation data, without considering the classification requirements of service defect types, or often directly define the problems as service quality defects, lacking research depth.

This paper establishes an express service defect evaluation model based on semantic network diagram- SERVQUAL model, and provides a service defect identification method combined with text mining tools and service quality type definition. By capturing the first-hand data of customers' feelings on the public platform, we can identify service defects, and the identified service defects are closely combined with customers' objective feelings.

Establishment of evaluation model of express service defects

Evaluation framework of express service defects

This paper constructs the defect evaluation model of express service based on semantic network diagram-SERVQUAL model (Figure 1). The key steps are as follows:

(1) Python is used to capture the express service comments from popular social platform and shopping platform which have sufficient and appropriate data resource, and SVM emotion analysis method is used to classify the express service comment set. It includes noun extraction, comment de duplication, mechanical compression and de duplication, deleting non text content, deleting short sentence comments, comment participles and removing stop words, extracting nouns and gerunds, and filtering irrelevant words to form a comment participle set to be mined.

(2) ROSTCM6 software is used to mine the comment word set, generate the semantic network diagram of express
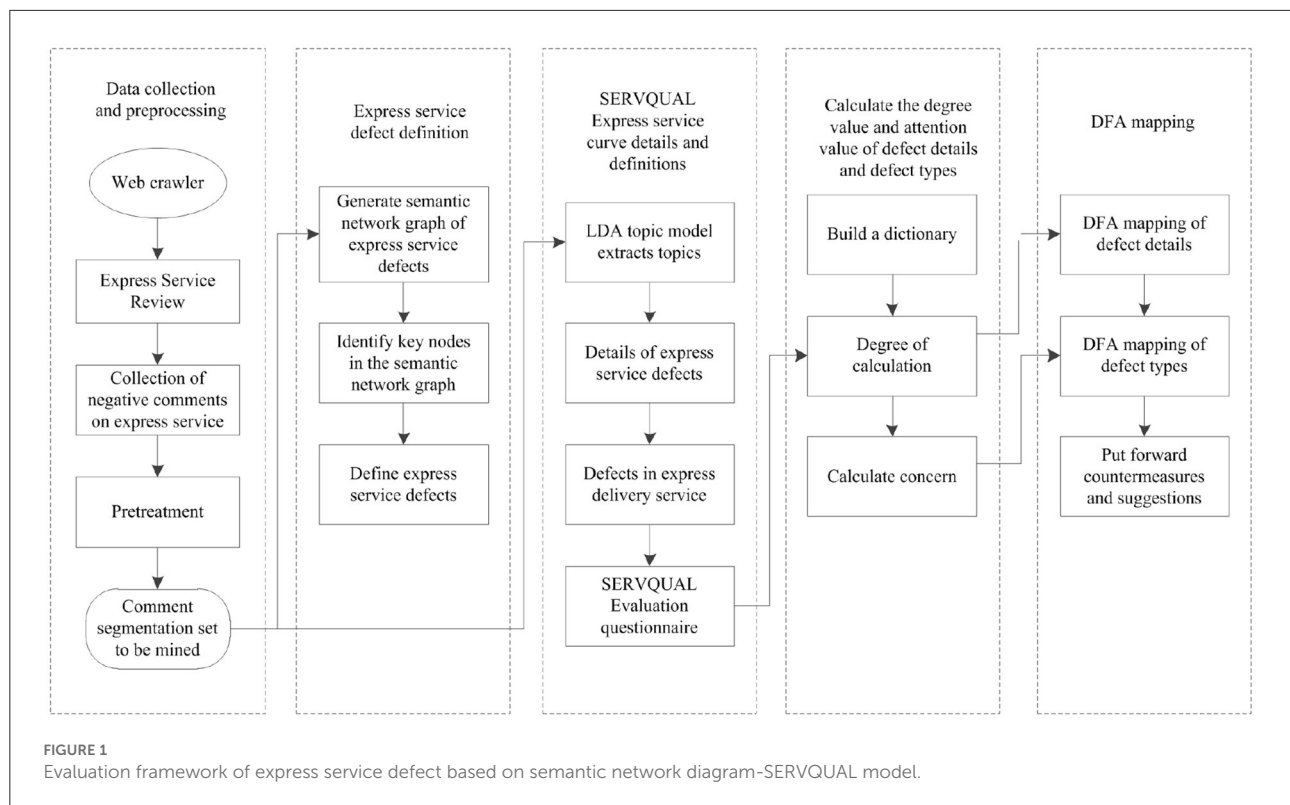
FIGURE 1
Evaluation framework of express service defect based on semantic network diagram-SERVQUAL model.

service defects, determine the key defect nodes, and define the express service defects.

(3) LDA topic model is applied to extract the topics of the comment word set to be mined, identify the express service problems, map them to the express service defect types in SERVQUAL model, and form a detailed list of service defects.

(4) The emotional dictionary and degree adverb dictionary of express service defects are constructed, to calculate the degree value and attention value of express service defects, and make z standardization to prepare for IPA mapping.

(5) Defect focus analysis (DFA) model is constructed according to the principle of IPA. The defect types of express service and relevant defect details of SERVQUAL model are mapped to DFA to identify key defects and defect details, so as to provide reference for improvement.

Calculation of degree value and attention value of express service defects

Construction of emotion dictionary and degree adverb dictionary of express service defects

According to the negative emotion dictionary in HowNet and NTUSD and the derogatory dictionary (35–37) proposed by Li Jun, an emotion dictionary with express service defects

is formed (Table 1). At the same time, referring to the degree adverb dictionary in HowNet, the common degree adverbs are divided into five categories, and the degree adverbs of each level are given decreasing weight value α respectively (Table 2).

Calculation of service defect degree value

Firstly, taking a comment in the word segmentation set of express service defect comments as the analysis unit, the emotion value of this comment is obtained by matching the feature word, emotion dictionary and degree adverb dictionary; each comment in the defect comment segmentation set is analyzed, to get the emotional value of n comments; Finally, it can calculate the average emotion value of n comments to get the emotion value of feature words. The calculation formula is as follows:

$$sen_i = E\left(\sum_{j=1}^{n} \alpha\, comment\_sen_{i,j}\right), i = 1, 2, ..., n; j = 1, 2, ..., n \ (1)$$

Where, sen_i represents the emotional value of a feature word; α represents the weight value of degree adverbs; If the comment contains characteristic words and emotional words, then $comment\_sen_{i,j}$ value is 1, otherwise it is 0.

In this paper, for each defect detail of express service, the average emotion value of the five feature words with the highest

TABLE 1 Emotion dictionary (part).

Emotion dictionary	Annoying, miserable, no one listens, disgusting, vomiting, unbearable, bad attitude, regret, ignore, shit, slow, mentally retarded, shutdown, dam it, too bad, fuck, garbage, fake, anxious, no, scolding, dying, despicable, unable to get through, die out, angry, failed to get through

TABLE 2 Dictionary of degree adverbs of express service defects (part).

Grade	Items	Weight value (α)
I. Extreme	Don't overdo, exceed, exceed heterodyne, get ahead, over, over	2.5
II. Very	However, many, invincible, heavy, strange, great, many, more, most, especially	2
III. More	No big deal, more, further, more, also, even, compare, further	1.5
IV. Some	Bit by bit, more or less, strange, also, more or less, some, slightly	1.0
V. Insufficiently	A little, not much, chatting, mild, weak, slightest, slight, tiny, relative	0.5

probability of occurrence is calculated as the defect degree value. The calculation formula is as follows:

$$Defect_i = \left(\sum_{j=1}^{5} sen_{i,j} \right), i = 1, 2, ..., n; j = 1, 2, 3, 4, 5 \quad (2)$$

The calculation formula of defect degree value of defect type of express service is as follows:

$$D_i = E \left(\sum_{j=1}^{5} Defect_{i,j} \right), i = 1, 2, ..., n; j = 1, 2, 3, 4, 5 \quad (3)$$

Calculation of attention value of defect index and dimension

The amount of comments on the topic indicates that the customer's attention to the topic is basically consistent with the result of customer perception [38], and the amount of reading on the topic also reflects the customer's attention to the topic [39]. Therefore, this paper uses two kinds of indicators: comments and reading to calculate the attention value of express service defects.

Firstly, the feature word-comment participle word pair is matched. If the word pair is matched, the comment amount

of the feature word is increased by 1; Secondly, it makes the feature word traverse each comment in the defect comment segmentation set. If the number of matched word pairs is x, the comment amount of the feature word is x. For the detailed defect, this paper calculates the sum of the comment amount of the five characteristic words as the comment amount of the defect, and the calculation formula is as follows:

$$C_i = \sum_{j=1}^{5} x_{i,j}, i = 1, 2, ..., n; j = 1, 2, 3, 4, 5 \quad (4)$$

Where, C_i represents the comment amount of a defect index of express service, and $x_{i,j}$ represents the comment amount of a feature word under the defect.

Secondly, the rules for calculating the reading amount of characteristic words are the same as above, and the formula for calculating the reading amount of defect index of express service is as follows:

$$R_i = \sum_{j=1}^{5} M_{i,j}, i = 1, 2, ..., n; j = 1, 2, 3, 4, 5 \quad (5)$$

Where, R_i represents the reading amount of a defect index of express service, and $M_{i,j}$ represents the reading amount of a feature word under the defect.

Finally, the comments and readings of the defect index of express service are given the weight value β_{i1}, β_{i2}, respectively, and the two are multiplied by the corresponding weight value and summed to obtain the attention value of the defect index of express service. The calculation formula is as follows:

$$Focus_i = \beta_{i1} \times C_i + \beta_{i2} \times R_i \quad (6)$$

Where, $\beta_{i1} = \dfrac{C_i}{C_i + R_i}, \beta_{i2} = \dfrac{R_i}{C_i + R_i}$.

The calculation formula for the attention value of the defect dimension of express service is as follows:

$$F_i = E \left(\sum_{j=1}^{n} Focus_{i,j} \right), i = 1, 2, ..., n; j = 1, 2, ..., n \quad (7)$$

IPA mapping between defect detail and defect type

Importance performance analysis (IPA) model, is called importance- performance analysis model, divides products or services into four quadrants by evaluating the importance

FIGURE 2
DFA model.
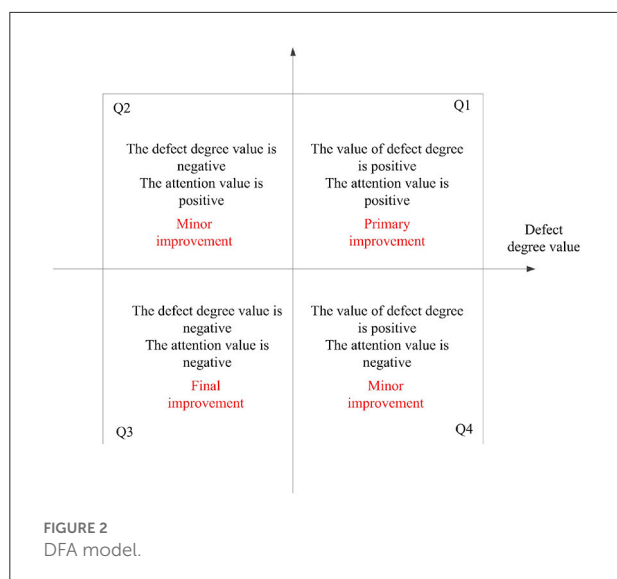
and performance of products or services, so as to formulate improvement strategies (40, 41). In this paper, the defect degree and attention degree are regarded as the two dimensions of IPA model, and the model is defined as defect focus analysis (DFA) model. The meaning represented by its four quadrants is shown in Figure 2. Z standardization of the results of defect degree value and attention value is conducive to dimensional elimination (42, 43). After mapping, key improvement defects can be directly identified to improve improvement efficiency.

Application research

Data collection and preprocessing

Collection of negative comment data of express service

This paper selects the top social media platforms and shopping websites in China, including Baidu Post Bar, Microblog, Zhihu, Douban and Taobao, as the data source, crawls the express service comment data from 2020 to 2022, and obtains 198,674 data in total.

SVM emotion analysis method is applied to classify the emotion of express service comments, and the mature practice is used for reference: the crawled comments are marked with emotion, and 8,000 negative comments and 8,000 other comments are obtained; Secondly, 16,000 comments are divided into training set and test set according to the ratio of 4:1; Then, the SVM module under Gensiem library is used to generate SVM classifier. The classifier is trained with training set and test set. After multiple training, the accuracy, recall and $F1$ values are 93.2, 92.8, and 88.38% respectively. The classification accuracy is high and the training is completed; Finally, the

trained SVM classifier is applied to the express service comment set, and 157,536 negative comment sets of express service are obtained.

Preprocessing of negative comment set of express service

The pre-process and results of negative comments on express service are shown in Figure 3. The whole processing includes weight reduction, mechanical compression weight removal, deletion of non text content, etc., and 133728 comments were obtained.

Definition of express service defects

Using ROSTCM6 software, it can quickly analyze the comment word set to be mined, and generate the semantic network diagram of express service defects as shown in Figure 4. As can be seen from Figure 4, the number of arcs of time, information, dispatch, express, receipt and insurance is >9, and the number of arcs of timeliness, SMS, attitude, freight and pick-up is >3. They are all key defect nodes in the semantic network diagram, which are in an important position in the semantic network diagram of express service defects.

Calculation of defect degree and attention of express service

Identification of defect details of express service items

One hot coding is used to encode the word items in the comment word set of express service defects to be mined, generate a mapping dictionary, and then represent each comment as a list. The collection of all lists constitutes the word bag model of the comment word set of express service defects to be mined. Secondly, LdaModel (LDA topic model) under the framework of Gensim, a third-party extension package of python, is used to extract feature words from the word bag model. Five feature words with the highest probability under each topic are set to extract the topics of express service defects. The identified 22 express service defect topics are taken as the detail defects of express service in SERVQUAL evaluation model (Table 3). The extraction process is shown in Figure 5.

Identify the defect type of express service

Learning from the SERVQUAL evaluation model built by Li and Hao (44) and Cao and Li (45), the detailed defects of express service are mapped to the corresponding service defect
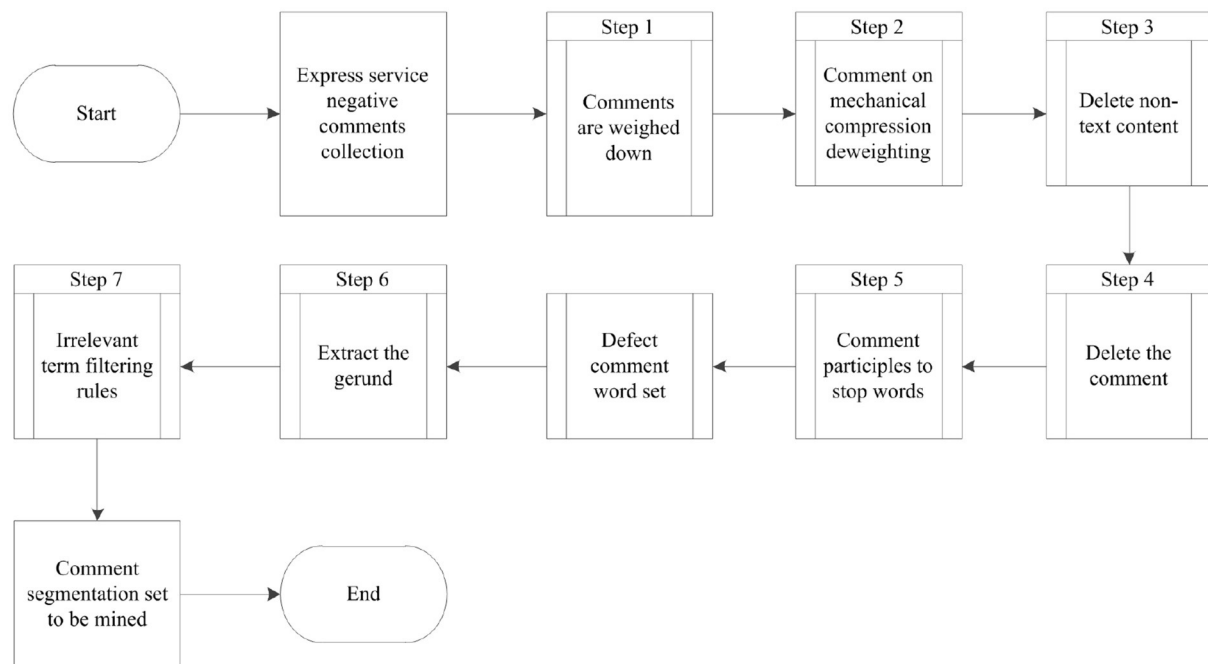
FIGURE 3
Processing process and result of negative comment set of express service.
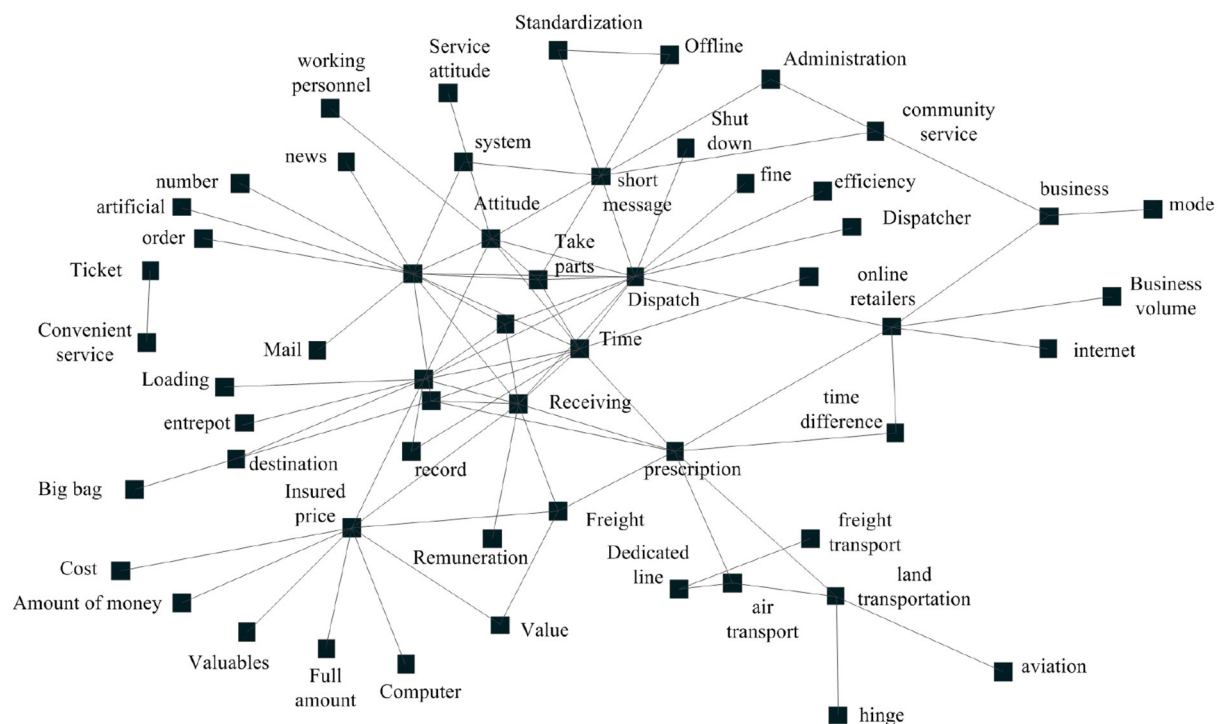
FIGURE 4
Semantic network diagram of defects in express service.

TABLE 3 22 topics of defect of express service.

	Defect of express service	Feature words
1	Unreasonable charging price	Freight, express fee, public, pricing, opinions
2	Unsafe valuables	Insurance, valuables, computers, laptops, electronic products
3	Unreasonable compensation price	Compensation, compensation, suggestions, store bullying, price
4	Delayed receipt	Receiving, overdue, remuneration, reaction, offline
5	Reject large parts	Large goods, emotional, heavy goods, sent off, delivery
6	Untimely delivery by express	Express, delivery, express delivery, punctuality, attitude
7	Poor integrity of outer packaging	Violence, case, outer package, sorting, inspection
8	Failing to feed back customer's complaints in time	Labor, special lines, public complaints, comments, excuses
9	Failing to feed back the customer's requirements in time	Requirements, time limit, number, consultation, private letter
10	Poor quality of staff	Deception, mistakes, quality, service awareness, defects
11	Poor diversity of transportation modes	Aircraft, land transportation, air transportation, location, aviation
12	Slow transportation speed	Express, snail, express, efficiency, speed
13	Low intensity of preferential activities	Discount, method, message, strength, receipt
14	Poor corporate image	Staff, care, salary, relationship, treatment
15	Poor convenience of customer receiving	Receiving, reasonable, distance, route, walking
16	Delivering dangerous express	Contraband, send, sender, postal law, danger
17	Poor professional ability of staff	Staff, ability, business process, problem solving, specification
18	Poor quality of enterprise management	Responsibility, supervisor, operation, leadership, management
19	Small coverage of express outlets	Distribution center, destination, hub, scope, business point
20	Service facilities are not modernized	Facility, robot, logic, modernization, business department
21	Poor reliability of cold chain transportation	Cold chain, loading, absurdity, trust, loss
22	Information cannot be obtained in time	Information, system, SMS, record, background

FIGURE 5
Process for identifying delivery service defects.
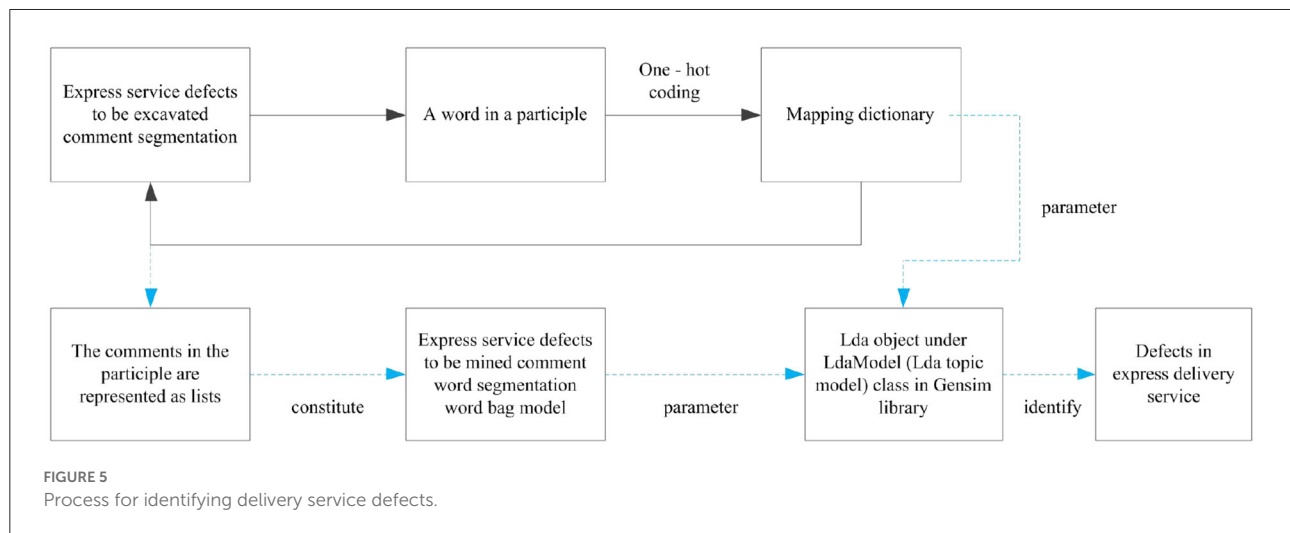
types, namely, tangibility, reliability, responsiveness, assurance, empathy and economy (Table 4).

Degree value and attention value of defect details and defect types

According to the calculation formula, the degree value and attention value of defect details and defect types of

express service are calculated, respectively, and the values are Z standardized (Tables 4, 5).

DFA mapping of defect

The defect degree value and attention value after z standardization are mapped to the quadrant diagram of DFA model, respectively (Figures 6, 7).

TABLE 4 The results of the degree value and attention value of express service defect.

Defect type	Degree detail	Degree value	Z-value of degree	Attention value	Z-value of attention
A: Tangibility	I. Poor quality of staff	1.28	0.39	12,383	−0.26
	II. Poor diversity of transportation modes	1.15	−1.85	8,713	−0.72
	III. Poor quality of enterprise management	1.35	1.60	11,943	−0.32
	IV. Service facilities are not modernized	1.21	−0.81	11,036	−0.43
B: Reliability	I. Reject large parts	1.20	−0.99	13,453	−0.13
	II. Untimely delivery by express	1.30	0.74	38,963	3.07
	III. Poor integrity of outer packaging	1.29	0.56	20,138	0.71
	IV. Delivering dangerous express	1.22	−0.64	11,615	−0.36
C: Responsiveness	I. Delayed receipt	1.27	0.22	19,204	0.59
	II. Failing to feed back customer's complaints in time	1.30	0.74	11,498	−0.37
	III. Failing to feed back the customer's requirements in time	1.23	−0.47	12,524	−0.24
	IV Information cannot be obtained in time	1.38	2.12	34,518	2.51
D: Assurance	I. Unsafe valuables	1.31	0.91	20,601	0.77
	II. Slow transportation speed	1.22	−0.64	9,638	−0.60
	III. Poor professional ability of staff	1.28	0.39	13,276	−0.15
E: Empathy	I. Poor corporate image	1.24	−0.30	12,782	−0.21
	II. Poor convenience of customer receiving	1.24	−0.30	11,080	−0.42
	III. Small coverage of express outlets	1.16	−1.68	9,864	−0.58
	IV. Poor reliability of cold chain transportation	1.19	−1.16	13,920	−0.07
F: Economy	I. Unreasonable charging price	1.28	0.39	7,833	−0.83
	II. Unreasonable compensation price	1.33	1.25	5,142	−1.17
	III. Low intensity of preferential activities	1.23	−0.47	8,063	−0.80

TABLE 5 The results of degree value and attention value of express service defect.

Defect dimension	Degree value	Z-value of degree	Attention value	Z-value of attention
A: Tangibility	1.25	−0.35	11,019	−0.51
B: Reliability	1.25	−0.35	21,035	1.5
C: Responsiveness	1.30	1.41	19,436	1.18
D: Assurance	1.27	0.35	10,879	−0.53
E: Empathy	1.21	−1.77	11,911	−0.33
F: Economy	1.28	0.71	7,013	−1.31

Discussion

Through the evaluation model of express service defects based on semantic network diagram and SERVQUAL model, we have the following findings:

(1) Although defect details can been identified (as shown in Table 3) through text mining technology, but it is very efficient to classify defect details by using SERVQUAL model, and then can help the managers to formulate the service improvement policy.

(2) Using defect degree and defect concern degree, we can more effectively improve the express service quality to improve customer satisfaction.Those specific defects with low degree value and low attention value, such as A-I, A-III, C-II, D-III, F-I, F-II shown in Q4 of Figure 6, may not have priority to improve, because improving these defects don't meant quickly improving customer satisfaction. Similarly, D and F in the Q4 of Figure 7.

(3) Combined with the quadrant positions of defect details and defect types in Figures 6, 7, the improvement order of service quality is determined, as shown in Table 6.

According to the above table, the following improvement countermeasures are put forward:

(1) In terms of responsiveness, it should firstly improve the specific problems of untimely receipt and
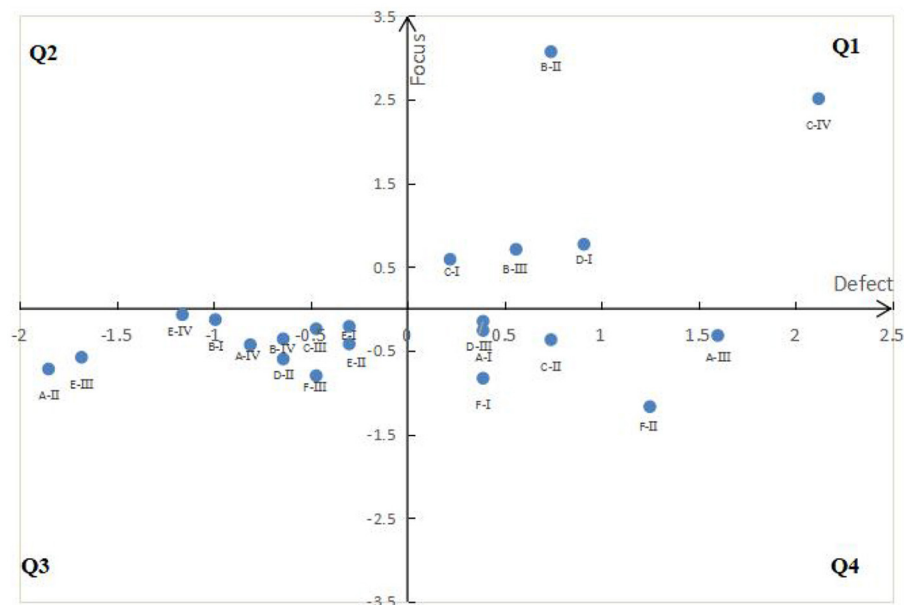
FIGURE 6
DFA diagram of defect detail.
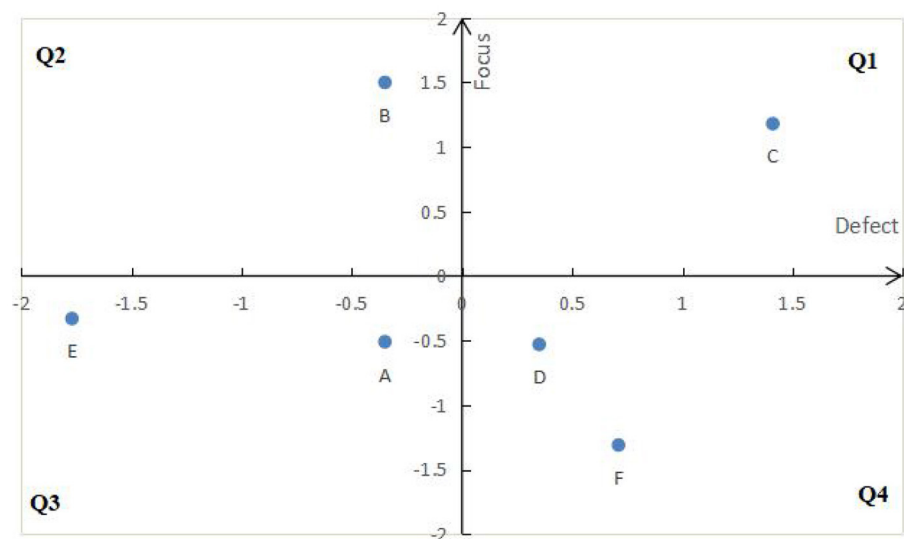
FIGURE 7
DFA diagram of defect type.

untimely access to express information, and then improve the complaint defects of untimely feedback to customers.

(2) In terms of assurance, it should firstly improve the unsafe defects of valuables, and then improve the poor professional ability of staff.

(3) In terms of economy, it is necessary to improve the unreasonable charge price and unreasonable compensation price.

(4) In terms of reliability, it is necessary to improve the delay of express delivery and the poor integrity of outer packaging.

TABLE 6 Improvement order of defect dimension and defect index.

Improvement order	Defect type	Defect detail
Primary improvement	C: Responsiveness	B-II: The express delivery is not timely, B-III: Poor integrity of outer packaging, C-I: Untimely receipt, C-IV: Express information cannot be obtained in time, D-I: The valuables of the representative are not safe.
Secondary improvements	B: Reliability, D: Assurance, F: Economy	A-I: Poor quality of staff, A-III: Poor quality of enterprise management, C-II: Untimely customer feedback, D-III: Poor professional ability of staff, F-I: Unreasonable charge price, F-II: Unreasonable compensation price
Finally improvements	A: Tangibility, E: Empathy	11 (omitted)

Conclusion

This paper constructs an evaluation model of express service defect based on semantic network diagram- SERVQUAL, analyzes the express comments on social platforms and shopping websites through text mining technology, extracts the theme by LDA model, comprehensively analyzes and quantitatively calculates the express service defects by using semantic network diagram and SERVQUAL model, identifies the main defects of express service, and puts forward the improvement direction. Through the data mining and calculation of China's express service, the effectiveness and practicability of this model are verified, which provides guidance for the express service industry to improve the service quality. The research of this paper can be applied to the defect identification of other service fields, such as aviation service, tourism service, catering service, medical service, insurance service, telecommunications service and so on.

The research of this paper has the following limitations: firstly, it takes the negative comments of online comments as the data source, but does not consider eliminating malicious comments, which may reduce the objectivity of the data source; Secondly, when measuring the attention value of express service defects, only two indicators of comment volume and reading volume are selected, without considering other factors; Thirdly, the effect of improvement countermeasures was not demonstrated to prove the accuracy of defect identification. Future research work can be deployed in the above aspects.

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

SG and KW: writing—original draft preparation. LG and JL: editing data curation and supervision. All authors contributed to the article and approved the submitted version.

Conflict of interest

Author JL was employed by the 716 Research Institute of China Shipbuilding Industry Group 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.

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Impact of smart health systems on the behavior of older adults under community healthcare

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Background: With the trend of world population aging, a good community health care system will determine whether the elderly can get good medical conditions. How to improve the community health care system can study how the behavior of the elderly affects it.

Objective: This paper is based on the analysis of the current situation of population aging at home and abroad.

Methods: On the premise of analyzing the demand and behavior of elderly people seeking medical treatment and the function of community health service institutions. Literature research was conducted to analyze the influencing factors of community health care needs and elderly people's medical seeking behavior at home and abroad. Then the elderly in Tianjin were investigated by issuing questionnaires, and the law of medical treatment behavior of the elderly in Tianjin was calculated. Combined with the results of relevant investigations abroad, the common phenomenon is summarized. Finally, the analysis method of intelligent medical system is proposed, and the design process of system acquisition module and user usage mode are given.

Result: The smart medical system can bring great convenience to the elderly and community healthcare.

Discussion: It emphasizes the powerful functions of smart health systems and their future importance for the health care of the elderly.

KEYWORDS

aging population, medical behavior, community healthcare, smart healthcare, public health

Introduction

Aging population

The aging trend of the world population

Population aging is an inevitable result of demographic transition and an important issue facing human society in the 21st century. Since the 21st century, the world as a whole has entered an aging society. The population aging degree of developed countries has been significantly deepened, and developing countries have not yet entered the ranks of aging. From a global perspective, in 2000, the total population of the world was 6.14 billion, which will increase to 7.79 billion in 2020, an increase of 1.65 billion in 20 years; at the same time, the population of people aged 60 and above has increased from 610 million to 1.05 billion people, an increase of 440 million people; in 2000, the proportion of the elderly population aged 60 and above was 9.9%, which is on the eve of an aging society.

During the same period, the population of the elderly aged 60 and above in developed countries increased from 230 million to 330 million, an increase of 100 million, and the proportion of the total population increased from 19.5 to 25.7%, an increase of 6.2 percentage points. The degree of population aging is relatively deep and similar. Much higher than the world's overall level. The number of elderly people aged 60 and over in developing countries (excluding China) increased from 250 million to 470 million, an increase of only 220 million, and the proportion of the total population increased from 6.8 to 9.2%, an increase of 2.4 percentage points. The population is aging. The degree of aging is relatively mild and the process is significantly slower than that of the world, and it has not yet entered the aging society as a whole, as shown in Table 1.

The aging of the world's population shows the following trends (1).

① The world has entered the process of population aging, and developed countries are at the forefront. The pace of population aging in China is significantly faster than that of developed countries and faster than that of the world.
② Japan is the most aging country today, and China has not yet entered the ranks of countries with serious population aging. China's aging process is significantly faster than that of the United States, Germany, Russia and other countries, and slower than Japan, South Korea, and Finland.
③ The population aging trend in developed countries is obvious. China's aging degree is heavier than the overall level of the world, but significantly lower than that of developed countries.
④ The degree of aging in developed countries in Japan and Europe is generally relatively deep, while that in China is relatively light, and the trend of aging in developing countries such as India and Nigeria is not yet obvious.
⑤ The aging process of the world's population continues to advance. Developed countries have entered a severely aging society, and developing countries will also enter an aging society. China's aging and low birthrate are developing rapidly.

The trend of population aging in China

The results of China's seventh national census show that the population aged 0–14 is 253.38 million, accounting for 17.95%; the population aged 15–59 is 894.38 million, accounting for 63.35%; the population aged 60 and above is 264.02 million, accounting for 18.70% % (including 190.64 million people aged 65 and over, accounting for 13.50%) as shown in Figure 1.

The population aging pressure during the "14th Five-Year Plan" period is greater than that during the "13th Five-Year Plan" period. The 1962–1976 baby boomer population will age in the next 5–10 years. It is expected to enter a super-aging society with a proportion of more than 20% around 2033, and then continue to rapidly rise to 35% in 2060.

China's population aging presents the following five characteristics (1).

① The size of the elderly population is huge.
② The speed of aging is fast.
③ The problem of advanced age and empty nest is becoming more and more prominent.
④ The elderly dependency ratio is rising sharply and the burden of old-age care is increasing.
⑤ Aging before getting rich.

Healthcare needs and behaviors of older adults

As we all know, with the increase of human age, the functions of all aspects of the body weaken, resulting in the elderly becoming a disease-prone population, especially chronic diseases, which have a long course of disease and require long-term follow-up treatment. In addition, although the aging process in China is relatively slow, due to the large population base and the aging speed is gradually accelerating, the degree of aging varies in different regions.

According to a survey by the Health Information Resources Research Center of Huazhong University of Science and Technology (2), first of all, what the elderly need most is general health services and daily preventive health care; in terms of consumption expenditure, the food and medical expenses of the elderly occupy the top two daily consumption expenditures, followed by the provision of offspring and entertainment. Obviously, medical care Expenses have become a very important expense in the daily life of the elderly. Secondly, the results of the survey on the behavior of the elderly in seeking medical treatment show that 80% of the elderly will choose different medical institutions for medical treatment when they feel that they are mildly ill. The rest choose individual clinics and army/enterprise hospitals; and when they feel seriously ill, the vast majority of the elderly will go to medical institutions for medical treatment, and the most elderly people choose district, provincial and municipal hospitals for medical treatment. At the same time, in both cases, there is a situation of illness without medical treatment, and the economic situation is the biggest reason. When investigating the reasons why the elderly choose medical institutions, the following conclusions are drawn: the choice of medical institutions in the elderly's medical behavior is mainly affected by convenience, medical level, and medical expenses. The elderly have a clear preference for medical institutions with close distance/convenient transportation, high medical level, good reputation, good attitude of medical service personnel, reasonable service price, short waiting time, advanced equipment and complete facilities, and comfortable medical environment. The medical level is the most important factor affecting the elderly's choice of medical treatment, followed by

TABLE 1 Population aging in the world and China from 2000 to 2020 (World Census Report).

Classification	Total population/billion people			60+ population/billion people			60+ proportion of population/%		
	2000	2010	2020	2000	2010	2020	2000	2010	2020
World	61.4	69.6	77.9	6.1	7.6	10.5	9.9	11.0	13.5
Developed countries	11.9	12.3	12.7	2.3	2.7	3.3	19.5	21.8	25.7
Developing countries (Excluding China)	36.4	43.2	50.5	2.5	3.2	4.7	6.8	7.5	9.2
China	12.6	13.4	14.2	1.3	1.8	2.6	10.0	13.3	18.7

FIGURE 1
The results of the seventh national census (Sixth National Census Report).
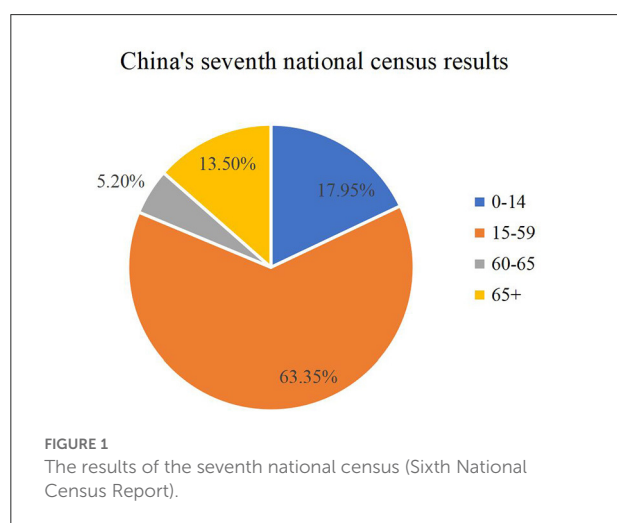
reputation and service price. Other influencing factors can be summarized as institutional service level factors (3).

It is also a top priority to promote the development of community-based basic medical institutions. Due to the inconvenience of the elderly, the elderly should consider the convenience requirements more when choosing medical institutions for medical treatment. Therefore, the nearby community and street health service centers should be the places for the elderly to seek medical treatment. The first choice institution; however, the medical service level of primary medical institutions is relatively lower than that of large hospitals at the provincial and municipal levels, which cannot meet the needs of the elderly for the service level of medical institutions. There are various problems of "difficulty in seeing a doctor" such as long waiting times and long distances for medical treatment. In response to this problem, the health service level of primary medical institutions should be strengthened, and barrier-free passages should be set up for the elderly in each medical institution, so as to reasonably guide the flow of medical treatment choices of the elderly, and strive to alleviate the problem of "difficulty in seeing a doctor" in the elderly's medical treatment. On the other hand, the government should strengthen the management of medical services in various institutions, standardize the medical treatment process, control medical expenses, and use the basic drug system, etc., to form a reasonable medical price mechanism, and alleviate the problem of "expensive medical treatment" for the elderly (4).

Community health service

Community health service is under the leadership of the government, community participation, and the guidance of higher-level health institutions, with people's health as the center, family as the unit, community as the scope, and demand as the orientation, with primary health institutions as the main body, and general practitioners as the main force (5) resources and professional technology, actively provide all residents of the community, especially women and children, disabled, elderly and other key service objects, establish health records, formulate community health plans, provide diagnosis and treatment services, prevent and treat chronic diseases, and conduct health education, etc. Basic health services are economical, convenient, comprehensive and effective. They aim to solve the main health problems in the community and meet the needs of basic health services. They are the foundation and core of the health system and an important part of community construction (6, 7).

With the increasing progress of science and technology and culture, in order to meet people's growing demand for basic health services, community health services are an effective means to adjust the rational distribution and allocation of health resources. During the transition period of the economic system, some new contradictions and new problems have emerged, which are mainly manifested in the following aspects: ① the rapid growth of drug costs and heavy personal burden; ② the large disparity in the allocation of health resources between urban and rural areas; ③ the continuous decline of the efficiency of medical services; ④ the aging population The process of transformation is accelerated. These problems also affect the health behavior of the elderly.

Community health service centers, as primary medical institutions, are an important part of urban health work and the basic link to achieve the goal of primary health care for everyone (8). It serves all residents in the community widely,

and it is inclined to key groups such as the elderly, the weak, the sick and the disabled. For the elderly who are aged at home in the community, the convenience of medical treatment in the community plays an increasingly important role in the protection of their health and quality of life.

Literature review

Research on the demand for community health services at home and abroad

Current status of foreign research

Developed countries entered an aging society many years earlier than China. In the mid-1990s, the international community began to propose to minimize the number of elderly people changing old-age places, and to make the elderly live in the living environment they are familiar with as much as possible. To obtain long-term and continuous elderly care services, and advocate the establishment of a "continuous care" elderly care service system. Developed countries such as the United Kingdom, the United States, and Japan have successively established long-term care systems in line with their national conditions. The elderly health care service system is relatively complete, and the community elderly medical network framework with multiple levels of medical treatment, health care, and nursing has been relatively complete.

The United Kingdom has become a country with an aging population as early as 1929, and its pension model is mainly a community care model consisting of "In-community care" and "Community care" (9), the difference lies in whether the government directly intervenes. The former is a normative old-age care with government intervention, while the latter is a non-normative old-age care without direct government intervention, usually through blood or moral relationships, i.e. family members, neighbors, friends, charities and non-profit organizations. Organization, etc., to maintain (10).

The United States entered an aging society as early as around 1940, and now a relatively mature and comprehensive market-oriented elderly care service industry has been formed. It generally adopts the model of commercial insurance, emphasizing the right of the elderly to choose independently, and can freely insure according to their own needs. The main feature of the old-age care model in the United States is that under the market economy system, the government guides and supervises its policies, and develops long-term care into an industry. At present, a pension pattern with coexistence of various models such as PACE, HCBS, CMO, ASAP, and RCC (11) has been formed.

Japan's adoption of the Nursing Insurance Law first solved the worries for the elderly and their families economically, and the elderly care service industry has achieved great development. At the same time, it has also alleviated the "press bed" that

hospitals deliberately choose to be hospitalized because the elderly want comprehensive care. In this way, the cost of medical and elderly care institutions is reduced, the medical expenses of the elderly are reduced, and the burden on the government and society is also reduced. The grassroots communities in Japan generally have small-scale, multi-functional and community-based service facilities, which are the hardware guarantee for home care. With the continuous development of Japan's long-term care insurance system, the academic community has made a systematic study of its development status, existing problems and reform directions. Anonymous believes funding sustainability can be addressed from a business perspective (12); Imai et al. believe that the advantage of the long-term care insurance system is that the elderly can obtain long-term professional medical care services in institutions other than hospitals, which satisfies the wishes of the elderly family for retirement (13). Shimizutani discussed the future reform trends of the long-term care insurance system, using data to study input costs, incentive mechanisms, etc. from a micro perspective (14).

Domestic research status

There are three basic pension models in China: family pension, institutional pension and community home-based pension (15). The increasingly severe aging trend has brought challenges to these three pension models. The traditional family structure has been transformed into a "4-2-1" structure, and the problem of insufficient motivation for the development of family pension is becoming more and more serious. Restricted by the lack of institutional resources and insufficient capital investment. Community-based home-based elderly care can provide the elderly with services such as life care, rehabilitation care and spiritual comfort. It can alleviate the pressure of children's care for the elderly and improve the quality of life of the elderly in their later years. However, (16) a major challenge faced by community-based home care is how to solve the increasingly poor health problems of the elderly at home.

In recent years, the local pilot work of the combination of medical care and nursing has provided empirical materials for the research. Beijing, Shanghai, Qingdao, Chongqing and other places have carried out practice and formed a model with local characteristics. Liu Shiyang conducted a survey on various medical and elderly care institutions in Beijing and put forward multi-level suggestions (17). Shen Wanwan explored the optimal mode of cooperation between Shanghai elderly care institutions and community health service centers (18). Starting from the background of Qingdao's medical and elderly care integration model, Li Jie analyzed the operation of Qingdao's medical and elderly care integration mode (19). Taking Banan District, Chongqing City as an example, Jing Sixia summed up the service model of combining medical care and elderly care in line with the actual characteristics

of Southwest China (20). In 2017, General Secretary Xi Jinping also clearly pointed out in the report of the 19th National Congress of the Communist Party of China that it is necessary to implement a healthy China strategy, actively respond to the aging of the population, build a policy system and social environment for the elderly, filial piety and respect for the elderly, promote the combination of medical care and elderly care, and accelerate the cause of aging and industry development.

A study on the medical treatment behavior of the elderly

Foreign research on the behavior of the elderly in seeking medical care

This paper divides the foreign research on medical treatment behavior into the following three aspects: theoretical research on medical treatment behavior, model research on medical treatment behavior, and research on influencing factors of medical treatment behavior.

Research on medical behavior theory research (21): The behavior of seeking medical treatment is a series of behaviors that people take the initiative to take medical measures when they feel unwell, in order to find the cause of the disease and reduce the harm caused by the pain. Research on the model of influencing factors of medical treatment behavior: foreign scholars mostly use discrete choice model to explore the choice behavior of resident medical institutions (22, 23) explored the relationship between Vietnamese residents' choice of different medical institutions and their participation in different medical insurance; Hanson et al. (24) discussed the influence of factors such as service quality, technical level, medical expenses and drug prices of medical institutions on patients' medical behavior; Wang et al. (25). A multivariate logistic model was used to explore the effects of insurance characteristics and residents' income on the patient's choice of medical treatment in three levels of medical institutions: village clinics, township health centers and county-level hospitals. Based on the above studies, it can be seen that most of the foreign studies on the impact of residents' medical treatment behavior use the regression model of related variables, especially the probit model and the logistic model are widely used (21). Foreign research on factors of medical seeking behavior can be roughly divided into the following three types: first, to explore the influence of medical institutions' technical level, service quality, medical price, medical distance and other factors on patients' medical seeking behavior choice; Secondly, the influence of family characteristics and personal characteristics of patients on the choice of medical institutions was discussed. Third, explore the influence of medical insurance participation on patients' choice of medical place.

Domestic research on medical treatment behavior of the elderly

In the domestic research on medical treatment behavior, in the early stage of research methods, mainly through data description and analysis, especially the influencing factors of patients' choice of medical institutions. Ren Xiaohui and others explored the influence of medical insurance participation on patients' choice behavior of medical institutions, initiative and timeliness of seeking medical treatment. Qian Dongfu took patients in economically backward remote rural areas as the research object, and applied a multivariate logistic model to analyze the influence of their choice of medical institutions and treatment methods on their medical behaviors (26). Zhang Bing and Wang Yiqiu conducted related research on the choice of residents' medical treatment behavior at the level of medical institutions, and found that when patients are seriously ill, they are more inclined to go to higher-level medical institutions for diagnosis and treatment. At this time, medical price factors have no significant impact on patients' choice of medical treatment behavior, and when the patient's physical fitness is good and suffers from minor or common diseases, the patient pays more attention to the medical price, and the price becomes a significant factor for the patient's choice of medical treatment behavior (27). Bao Yong et al. analyzed the medical treatment intention and influencing factors of residents in a community in Shanghai by compiling their own questionnaires (28). Jiang Jinqi applied a multi-factor logistic model to study the choice of medical treatment behavior of rural residents after illness, and found that in the early stage of the new rural cooperative medical system in 2004, the farmers who participated in the new rural cooperative medical insurance were more inclined to choose after illness. Go to a nearby clinic to seek medical treatment. However, by 2007, whether or not to participate in the new rural cooperative medical insurance has no significant impact on whether farmers go to the doctor when they become ill, but it increases the proportion of farmers who self-medicate (29).

Therefore, the research on the influencing factors of residents' medical treatment in China is mainly focused on the influencing factors of patients' choice of medical treatment, and patients' medical treatment behavior is mainly affected by material conditions.

Research questions

This paper is based on the background of population aging to study the behavior of the elderly, especially the impact of the health behavior of the elderly on community health care. As we all know, the health problems of aging are complex issues involving multiple levels. The rapid development trend of "aging society" will inevitably lead to changes in the national disease burden, financing and investment patterns. At the same time, the current situation of health care, provision and utilization

of health care services for the elderly in China is worrying. Compared with other countries, the health services for the elderly in China still need to be improved. What constructive measures can be taken? Finally, the social support system for elderly health services in China is lacking. China is in the process of building and improving the new medical reform medicine and public health system. Professional medical care resources for the elderly are even more scarce, and there is a lack of sociality outside other professional medical care institutions. Support institutions added that the sick elderly can only be cared for by their family members or hired social personnel, which directly increases the economic and psychological burden of the elderly family.

Research design

Research content

This article addresses the impact of older adults' behavior on community health care in the context of an aging world population. The general law of the behavior of the elderly is the main factor to promote the development of community medical care. According to different behaviors of the elderly, different measures should be taken to prescribe the right medicine, optimize the medical and health links, and comprehensively promote the medical alliance services. The hierarchical diagnosis and treatment model of referral, classification of acute and chronic diseases, and linkage between upper and lower levels" realizes family doctor contract signing and team building of general practitioners, provides convenient medical services for the elderly, improves the reform of the medical system, and implements "double sinking", two "Upgrade" project to speed up the development of grass-roots community health service institutions (12). Through the analysis and discussion on the development strategy of community health service institutions in Hedong District, Tianjin, we can provide better medical security for home-based elderly care, promote the comprehensive strengthening of community health services, reduce the increasingly severe burden of aging, and achieve healthy elderly care.

Research methods

This paper analyzes the impact of elderly behavior on community health care under the background of aging (as shown in Figure 2) by comprehensively using literature analysis, questionnaire survey and computer intelligent medical system analysis, and provides suggestions for the realization of healthy old age and the development of community health care. Constructive advice.

FIGURE 2
Research flow chart.
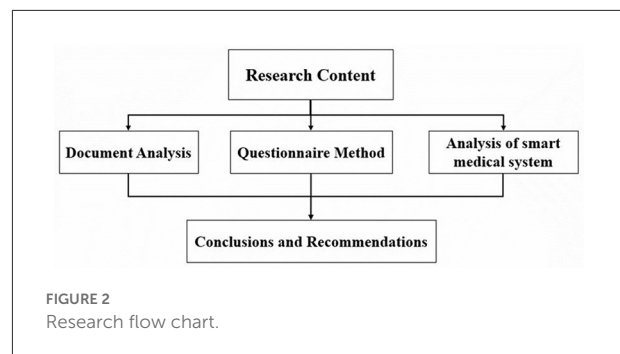
Literature analysis method

Collect a large number of literature materials related to old-age care, medical care, community health services, and the combination of medical care and elderly care, organize and classify, read and research, understand existing domestic and foreign related theories and research results through literature materials, and sort out domestic The development of foreign community health service institutions provides a theoretical basis for the writing of the thesis.

Questionnaire survey method

A survey questionnaire was designed to understand the cognition, demand and use of community health service institutions among the elderly groups in six districts of Tianjin City as an example, and relevant conclusions were drawn through quantitative analysis of the questionnaire survey.

Computer intelligent medical system analysis method

Through the regional medical information platform for health records created in recent years, the most advanced Internet of Things technology is used to realize the interaction between patients and medical personnel, medical institutions, and medical equipment, and gradually achieve informationization. The smart system represented by smart access control and smart community conducts data analysis on the daily behavior patterns of the elderly on the big data platform, draws conclusions about the general behavior of the elderly, and gives corresponding measures.

Innovations and shortcomings

Scholars at home and abroad have done a lot of research on the combination of medical and nursing care in recent years, and the theoretical results are relatively rich. After consulting a large number of literature and materials, they found that the focus of attention is mainly on how to break the system

fortress and establish hospitals and sanatoriums that integrate medical and nursing care. In China, more attention is paid to the feasibility and policy implementation of the combination of medical care and elderly care. There are relatively few studies on how to develop community health service centers in order to provide better health services for the elderly at home in the community. This paper grasps the trend of the times, studies the age-appropriate development of community health service institutions as a breakthrough point, and proposes countermeasures from the perspectives of human resources, hardware facilities and system construction to promote the development of community health service centers.

Due to the limitation of human factors, this paper adopts the questionnaire survey method which is more convenient for sampling survey. The data results of the survey are based on the 365 questionnaires collected, which may lead to biased conclusions; and personal thinking is not comprehensive enough, which may also affect the quality of research. As a path study on the development of grass-roots community health service centers under the background of population aging, if time and samples are sufficient, I think this paper has more room for further discussion (30).

Research questions and hypotheses

P1: What are some constructive suggestions for improving the national health services for the elderly?

This paper is based on the background of population aging to study the elderly behavior, especially the elderly health behavior on the community health care. As is known to all, the aging health problem is a complex problem involving multiple layers. The rapid development trend of "aging society" will inevitably lead to changes in the country's disease burden, financing and investment pattern. At the same time, the current situation of health care and medical insurance provision and utilization in China is worrying. Compared with other countries, China's health services for the elderly still need to be improved. What constructive measures can be taken? The lack of social support system of elderly health services in China, it is in the construction of the new health care medicine and public health system and perfect, professional medical care for elderly people more scarce resources, lack of social support besides other professional medical and health institutions complement, sick old man only by family members or hire social personnel's care, This directly aggravates the economic and psychological double burden of elderly families.

H1: The background of the aging population in the world and the lack of social support system for health services for the elderly in China.

H2: China's community healthcare system has increased physical security requirements based on an aging population.

H3: Smart health systems have a positive effect on the medical behavior of the elderly.

Questionnaire method

Research object

The subjects of this study were the elderly in urban areas of Tianjin, and a sample survey was conducted on the living conditions, health conditions, and health service needs of the elderly over 60 years old in the community. A total of 400 questionnaires were sent out, and 365 were recovered, with a recovery rate of 91.25%, of which 365 were valid questionnaires.

A random sampling method was adopted to select six main urban areas in Tianjin, and three streets were randomly selected in each urban area for questionnaire surveys. The surveyors issued questionnaires to the respondents in a uniform manner with the same survey standards and in a one-to-one manner. At the same time questionnaire survey results are promised to the respondents confidentiality, will not disclose personal privacy.

Data processing

After collecting and arranging the data obtained from the questionnaire survey. Epidata was used to establish a database, double-checked and entered, and SPSS 19.0 software was used for statistical analysis of the data.

The basic situation of the data results

The respondents of this survey are the elderly over 60 years old, including 165 males and 200 females. The average survey age is 67.5 years old. The youngest is 61 years old and the oldest is 89 years old. 81% of the survey respondents are concentrated in the age group of 60. Between 72 years old. The educational level of the respondents is concentrated in primary school, junior high school, and high school, accounting for 28, 26, and 25% respectively. The illiterate and highly educated people are <21%. Most of the spouses of the respondents in this study are still alive, the proportion is higher than 75%. 48.77% of the elderly feel that their health status is average, as shown in Table 2 below, more than 37% of them feel that their health status is good, and only 11% of them feel that their health status is not good. Therefore, what the elderly need most is general hygiene services and routine preventive care. In terms of consumption expenditure, it can be seen from Table 3 below that food expenses and medical expenses occupy the top two positions in daily consumption expenditures, followed by the supply of offspring and entertainment. Obviously, medical expenses have become a very important part of the daily life of the elderly expenses.

A survey on the medical consumption behavior of the elderly in urban areas of Tianjin found that among 365 elderly people,

TABLE 2 Individual self-perceived health status of the elderly.

Perceived health status	Frequency (Number)	Percentage (%)
Very good	45	12.33
Good	98	26.85
Generally	178	48.77
Not good	36	9.86
Very bad	5	1.37
Can't answer	3	0.82
Total	365	100

TABLE 3 Consumer spending of the elderly.

Expenditures	Frequency (Number)	Percentage (%)
Food expenses	361	98.90
Medical fees	312	85.48
Supply offspring	135	36.99
Entertainment	89	24.38
Housekeeping	69	18.90

67.4% of the elderly chose to go to a medical institution for medical treatment when they were physically and mentally unwell, 30.7% of the elderly chose to go to the pharmacy to buy medicine first, and 1.9% of them chose to go to the pharmacy first of older adults choose not to treat at first. When choosing a medical institution for the first consultation, 33.2% of the elderly chose to go to a general clinic, 48.5% of the elderly chose to go to a community/township health center, 15.1% chose a county/district hospital, and 3.3% of the elderly chose to go to a hospital above the county level. When choosing a medical institution, the elderly mainly focus on two factors: convenience (48%) and reasonable cost (29%). Level (0.5%) and other aspects are considered less. In the choice of medicines, the elderly are more concerned about the efficacy (43.8%) and cost (36.2%) of medicines, while the word-of-mouth (9.9%), brand awareness (3.0%) and pharmacy or hospital recommendation (7.1%) of medicines are more concerned with the elderly. Less attention. The majority of seniors' healthcare decisions are made by themselves (55.1%), followed by partners (26.6%) or husband and wife (13.2%), and fewer seniors make decisions by children (5.2%).

It can be seen that, as a first-tier city in China, the consumption level of the elderly in Tianjin is obviously higher than that in other areas. However, there are still many elderly people who consider the cost factor when choosing medical institutions, and also consider the price when choosing medicines. Therefore, an obvious conclusion can be drawn. For the reform of social medical care, price fairness and even lowering the price of medical consumption are the top priorities,

and making the elderly willing to spend money on medical care is the only way to reform. As show in Tables 4, 5.

The questionnaire survey involves the participation of the elderly in medical security. From the survey results, the vast majority of the elderly enjoy medical security, and only a very small number of the elderly do not have medical security. Among the 365 valid survey respondents, specifically: 121 people participated in the medical insurance for urban employees, accounting for 34.38 of the total number; 132 people participated in the basic medical insurance for urban residents, accounting for 37.50% of the total number; There are 68 people with cooperative medical care, accounting for 19.32% of the total number; 25 people participating in commercial medical insurance, accounting for 5.68% of the total number; 19 people without any insurance, accounting for 3.12% of the total number. Among them, the proportion of medical insurance for urban employees and medical insurance for urban residents is similar, and the proportion is relatively high, the proportion of participating in commercial insurance is low, and the proportion without medical insurance is the least.

When choosing a medical institution for the first consultation, 77% of the elderly chose to go to community township health centers and general clinics, and only 23% of the elderly did not receive community health services, as shown in Table 6. This shows that when encountering health problems, community health care is the first choice for the vast majority of the elderly, and the quality of community health care directly determines the health behavior of the elderly.

Smart medical system analysis

With the rapid development of technologies such as big data, Internet+, and 5G, concepts such as smart medical care, "big health", and medical big data have appeared frequently, and have attracted great attention in the field of smart medical care at home and abroad (31). The core of smart health management, one of the important components of smart medical care, lies in the information data and electronic health records of patients (32). However, the inadequacy of current health management is limited by traditional medical methods, which can only go to a doctor or participate in a physical examination at a fixed time. Therefore, the important physiological parameters of patients cannot be monitored in real time and continuously, which leads to delays in discovering potential diseases and affects the most the best time for treatment. In addition, there are still many people in China who are not aware of basic chronic diseases such as cardiovascular and other basic chronic diseases, and the treatment rate is even lower. Almost more than half of the population has not implemented effective prevention and treatment (33). Basic chronic diseases are usually closely related to physiological parameters such as blood pressure, blood oxygen, body temperature, and respiration. In order to prevent

TABLE 4 Descriptive table of medical consumption behavior of the elderly in urban areas of Tianjin ($n = 365$).

Medical consumption behavior		Number	Composition ratio (%)
The first choice for mental and physical discomfort	Go to a medical institution	246	67.4
	Go to the pharmacy	112	30.7
	Without treatment	7	1.9
First when sick medical institution	General clinic	121	33.2
	Community/township health center	177	48.5
	County/District Hospital	55	15.1
	Hospitals above the county level	12	3.3
Key Factors in Medical Institution Selection	Medical convenience	175	48.0
	Reasonable cost	106	29.0
	Good environment	17	4.7
	High medical skills	62	17.0
	Careful	3	0.8
	High level	2	0.6
Key Factors in Drug Selection	Curative effect	160	43.8
	Cost	132	36.2
	Word of mouth	36	9.9
	Brand awareness	11	3.0
	Pharmacy or hospital recommendation	26	7.1
Decision makers in healthcare	Own	201	55.1
	Companion	97	26.6
	Husband and wife	48	13.2
	Child	19	5.2

and treat chronic diseases, it is very meaningful to continuously measure such physiological parameters. At the same time, the monitoring of human body posture can also be particularly important for the health management of the elderly (34).

In recent years, medical technology based on artificial intelligence has achieved rich research results, and has also occupied a very important position and role in the development of smart medical care, and is further opening a new era of smart medical care. Compared with the shortcomings of traditional medical management methods, which are backward and the measurement accuracy of physiological parameters is not high, the smart medical analysis method mentioned in this article is to design a system with embedded AI technology. access control technology. Through the core hardware platform, the received signals are subjected to quality evaluation, filtering, denoising, enhancement, feature extraction, heartbeat classification and other work processing, and then uploaded to the cloud through the module for health management of elderly users. At the same time, the system can also complete the interaction between users and doctors, and can further establish an individualized physiological parameter database, so as to realize the dynamic tracking management and disease prevention of diseases of the elderly.

TABLE 5 The distribution of medical insurance participation of the elderly ($n = 365$).

Type	Frequency (Number)	Percentage (%)
Urban Employee Medical Insurance	121	33.15
Basic Medical Insurance for Urban Residents	132	36.16
New rural cooperative medical care	68	18.63
Commercial medical insurance	25	6.85
None	19	5.21

Design of system acquisition module

The system acquisition module designed in this paper is shown in Figure 3. It mainly includes four parts: information perception, information transmission, signal processing, and signal feedback. The sensing part mainly includes sensors to collect the physiological parameters of the elderly; signal transmission mainly uploads the collected and preprocessed

TABLE 6 Frequency distribution of elderly people receiving community health services (*n* = 365).

Whether receiving community health services	Frequency (Number)	Percentage (%)
Yes	281	76.99
No	84	23.01

data to the terminal or cloud server through the module; Next, AI algorithms are required to evaluate the quality of the received signals, Filtering, denoising, enhancement, feature extraction, cardiac beat classification and other work processing; finally, the information processed by AI algorithm is transmitted to users and doctors, ECG database and health management center, and can be continuously tracked.

User usage mode

The user usage mode is a mode in which doctors use the system to diagnose patients, and patients can log in to the system to view their own diagnosis results. In order to realize this mode, the doctor needs to first receive the patient through the registered diagnosis module. If the selected patient has not applied for the collection terminal, he needs to fill in the patient's disease information, make a diagnosis, and provide the corresponding treatment plan. If the disease is serious, the doctor needs to guide the patient to register with the system and apply for the collection terminal; if the disease is mild, the diagnosis can be ended and the next patient can be selected until the end of working hours. If a patient needs to apply for a collection terminal, they need to enter the patient ID number in the information module to view their historical diagnosis data, and then use the medical auxiliary module to diagnose and obtain the treatment plan, enter it into the diagnosis dialog box and upload it to the database. In this way, patients can log in to the system to view the diagnosis results independently (35).

The overall frame diagram of the system reflects the data interaction mode of the smart medical system. The elderly can automatically collect the required data (heart rate, blood pressure, body temperature, etc.). Data collection system, ideally, the cloud will automatically analyze the health status of the elderly based on the collected data on the day. If any problem is found, it will alert the elderly to pay attention and upload the problem data to the community medical center for doctors to analyze and provide medical measures. In this way, the elderly can know their health status without leaving home. If necessary treatment is needed, they will also be recommended to the nearest community medical and health service center for diagnosis and treatment, so as to truly achieve old age with medical care.

Results and discussion

From the perspective of literature analysis, from the perspective of questionnaire survey, and from the perspective of smart medical care, this article studies the impact of the behavior of the elderly on community health care in many aspects. The following conclusions can be drawn:

(1) The vast majority of the elderly receive treatment at community health service centers, accounting for 77% of the surveyed.
(2) The two factors of convenience for medical treatment and reasonable cost are the main considerations for the elderly to choose a medical place. The elderly prefer to seek medical treatment nearby, and they also try to be frugal in consumption, and do not like to go to expensive medical places for consumption.
(3) The elderly who are close to the average think their physical health is average, and many elderly people think that their body is in a sub-healthy state.
(4) The smart medical system can bring great convenience to the elderly and community health care, and can connect the two more closely.

Based on the above conclusions, combined with the impact of the elderly's behavior on community health care, the following suggestions are given:

(1) Improve the preferential medical treatment system for the elderly, so that the elderly can enjoy better medical conditions with less money;
(2) Optimize and adjust the industrial structure of the geriatric medical industry; hospitals change their management mode, implement refined management, and optimize and adjust the medical service structure focusing on medical services for the elderly.
(3) It is necessary to strengthen the supervision and management of the geriatric medical market and improve the consumption environment of the geriatric medical market.
(4) Promote the smart medical system, so that more elderly people can enjoy the dividends of science and technology, so that the elderly and social medical care are more suitable.

Research conclusion and discussion

This article analyzes the characteristics of the world's aging population, starting with the trend of the world's aging population and the era of China's aging population. The article also researches the health care needs and behaviors of the elderly, and it can be seen that community health care is the key factor, and the availability of a good community health care system is directly related to the choice of health care behaviors of the elderly. The author also introduces the concept of community

FIGURE 3
System overall frame diagram.
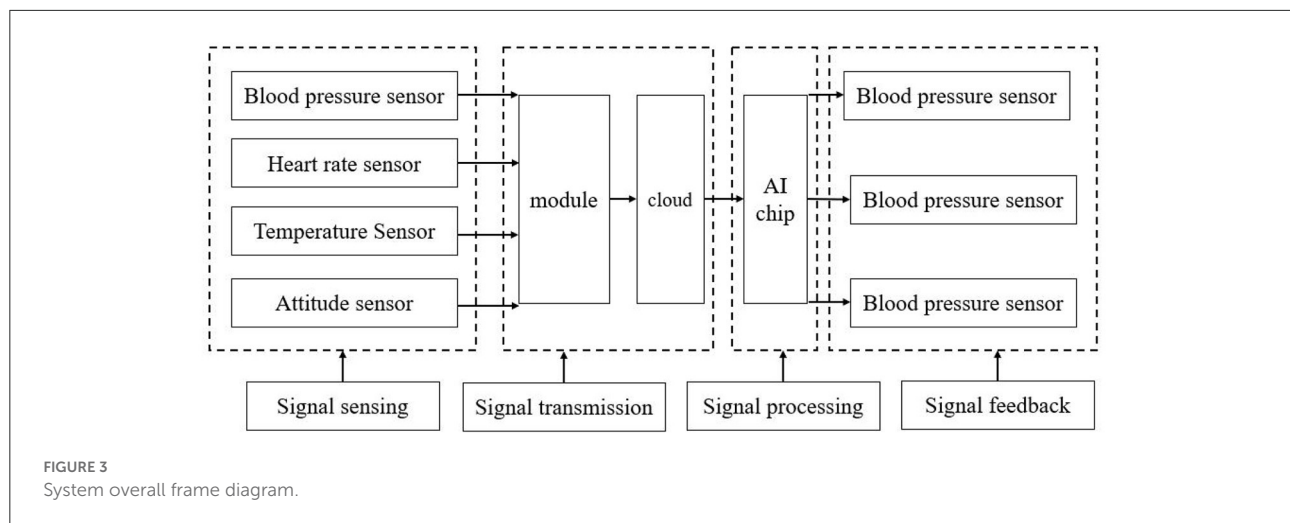
health service organization, which defines community health care more accurately.

In the content of the literature research section, the author conducts research from two perspectives, firstly, research on the demand side of community health services at home and abroad, in fact, research on the health care seeking behavior of the elderly at home and abroad, dissecting the material and intrinsic reasons.

The main core part of the article is the questionnaire research section, based on the results of the research and combined with the research questions and hypotheses we have some conclusions as follows.

(1) The majority of the elderly people accept to go to the community health center for treatment, accounting for 77% of the surveyed people.
(2) Convenience and reasonable cost are the two main factors that elderly people consider when choosing a place to go for medical treatment, and they prefer to seek medical treatment nearby and spend money as frugally as possible, and do not like to spend money in expensive medical places.
(3) Nearly the average elderly people think their health condition is average, and many of them think their body is in a subhealthy state.
(4) Smart medical system can bring great convenience to the elderly and community health care, and can link the two more closely together.

Regarding Q1, based on the above findings, the following recommendations are given in the context of the impact of older adult behavior on community health care.

(1) Improving the system of medical benefits for the elderly so that they can enjoy better medical conditions with less money.

(2) Optimize and adjust the industrial structure of the geriatric medical industry; hospitals change their management mode, implement fine management, and optimize and adjust the structure of medical services with a focus on medical services for the elderly.
(3) Strengthen the supervision and management of the geriatric medical market and improve the consumption environment of the geriatric medical market.
(4) Promote the smart medical system, so that more elderly people can enjoy the dividends of technology, and make the elderly more relevant to social healthcare (36–38).

Outlook

This article has been studied from several aspects. The literature survey method gives an understanding of the research on the behavior of the elderly at home and abroad in recent years as well as the research on the function of community health service centers; the questionnaire survey method takes a certain region as an example and speaks with data very strongly to convince the readers, but there are still certain shortcomings (39, 40): firstly, the questionnaire survey method can have more sample space in order to come up with more general laws; secondly, intelligent medical care is a good method, but the article still lacks some key technical means, which can be combined and analyzed by professional software afterwards to make the article structure more complete.

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, and writing-original draft preparation: JZ and LW. Methodology: JZ and KG. Data curation: KG. Writing—review and editing: LW, JZ, and KG. Supervision: JZ. 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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Evolutionary game analysis of community elderly care service regulation in the context of "Internet +"

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Background: As an upgraded form of the elderly care service industry, "Internet + Community Elderly Care" integrates information technology, artificial intelligence, Internet thinking, and the construction of community elderly care service mechanisms. Research on "Internet + Community Elderly Care" has become a focus.

Methods: The four-party evolutionary game model of elderly service regulations was presented, which consists of the government, providers, platforms, and elderly people. By using Lyapunov stability theory, the stability of each player's strategy selection was analyzed. Furthermore, the sensitivity analysis of the key parameters was discussed in detail using system dynamics.

Results and discussion: Online evaluations of elderly people have more positive effects on the regulatory system than offline evaluations. Both the penalties on providers and subsidies on platforms given by the government have thresholds. Moreover, government penalties for providers and subsidies for platforms could curb their speculative behavior and enable effective steering of providers and platforms.

Conclusion: The Omni-feedback mechanism for elderly people can effectively curb the speculative behavior of elderly care service providers and elderly care service information platforms. The government should dynamically adjust penalties and subsidy policies.

KEYWORDS

community elderly care, feedback mechanism, service regulation, evolutionary game, system dynamics

1. Introduction

Community elderly care can reduce the financial burden associated with aging (1) and meet the demands of the elderly in their homes (2–4). Therefore, community elderly care is an important model for assisting elderly people in adapting to the trend of social development and improving their quality of life in their later years. However, with the issue of an aging population becoming serious in some countries, including China, the drawbacks of the traditional community-based elderly care model have gradually emerged. For example, a lack of talents and professionalism (5–7), poor accessibility of services and single service item (5, 7, 8), difficult quality measurement, a lackluster

supervision and evaluation system (9), inefficient management, and a mismatch between supply and demand (5, 10, 11).

In recent years, with the development and proliferation of "Internet +" information technology, the mode of combining "Internet +" with the elderly care industry has gradually become a focus (12). The combination of "Internet +" and elderly care can better match the supply and demand of elderly care services, optimize the integration and allocation, promote the specialization, intelligence, and standardization of the elderly care services, and improve the service quality of elderly care (5, 13). Thus, the combination of "Internet +" and the elderly care industry has received the attention and support of governments in various countries. For example, Cherie and Sajda (14) pointed out that the US has been seeking to apply information technology to elderly care services and form a network of smart elderly care services. Schnell (15) introduced the relevant situation of smart health care in Japan, and the "Tokyo Model" smart elderly care community was created in Tokyo, Japan.

Similarly, in China, the government has issued a series of policies to encourage the development of new elderly care, especially "Internet + Community Elderly Care." In December 2016, China's State Council issued "Several Opinions on Fully Opening the Elderly Care Service Market and Improving the Quality of Elderly Care Service" (16), which promotes the integration of information technology, such as mobile Internet, with the elderly services industry. In April 2019, China's State Council issued "Opinions on Promoting the Development of Elderly Care Services," proposing to implement the "Internet + Elderly Care" action (17). In February 2022, China's State Council issued the "14th Five-Year Plan for the Development of the National Aging Cause and Elderly Care Service System" (18), which promotes Internet platform enterprises to match the demand for elderly care services and support the platform-based display of community elderly care service institutions. These proposed policies will promote "Internet+" elderly care service innovation. However, there are some problems with the practice of "Internet + Community Elderly Care." For example, some conflicts of interest among stakeholders may exist, the division of powers and responsibilities may not be clear, and there may be a lack of both online supervision and offline service tracking on the platforms providing information on elderly care services. These would lead to a lack of effective supervision of the elderly care service providers' service provision practices, which encourages the speculative behavior of elderly care service providers to provide substandard services. Therefore, the relationship among government departments, elderly care service providers, elderly care service information platforms, and elderly people should be properly discussed. Furthermore, the path of upgrading government policies should be explored to standardize the provider behavior of elderly care service providers and promote the healthy development of the "Internet + Community Elderly Care" industry.

Notably, the existing research on community elderly care is mainly focused on the concept of community elderly care (19), the demand for community elderly care (20, 21), the technology of community elderly care (22–25), and the model of community elderly care (1). However, there is little research on the quality of service in community elderly care. It is common knowledge that a strict regulatory system is conducive to the sustainable development of the elderly care industry (26). Based on this, some authors not only discussed how to improve the quality of community elderly care services, but also focused on improving the supervision of elderly care services. For example, Xu et al. (9) showed that the perception of the elderly in multi-attribute decision-making is ambiguous and established an effective evaluation method for the quality of intelligent community elderly services. Shao et al. (11) developed a model to screen performance optimization directions through sensitivity analysis conducive to the sustainable development of the community elderly care service system. Wang et al. (27) presented the problems in community elderly care through semi-structured interviews and provided some recommendations, including establishing a platform for government-citizen dialogue and establishing a sound monitoring and evaluation mechanism. Jiang et al. (28) analyzed the impact of government subsidies on the willingness of enterprises to provide high-quality services. Wang and Cui (29) discussed the impact of dynamic reward or penalty mechanisms on the self-discipline behavior of elderly care institutions. Under positive government regulations, Yue and Lin (30) pointed out that increased penalties can curb the speculation of service providers. Otherwise, penalties imposed by the government will be ineffective.

The above research is mainly based on the dominant role of government, with less consideration given to other subjects in the elderly service system. In supervising elderly services, government regulations can effectively improve the service quality of elderly care institutions (31). For "Internet + Community Elderly Care," the government needs to allocate more resources to arranging, planning, and regulating the supply of community elderly care services. The overall planning capacity of the government may be inadequate. Consumer feedback also has an impact on product quality and corporate behavior. For example, He et al. (32) pointed out that, as end users, consumers have the right to provide feedback on product quality. Chevalier et al. (33) showed that consumer feedback evaluation has an impact on product quality. Yang et al. (34) concluded that consumers' feedback evaluations would affect potential customers' purchase decisions. Zheng et al. (35) believed that the online reputation mechanism based on feedback could inhibit the speculative behavior of enterprises. Zhang et al. (36) analyzed the development of e-commerce platforms and logistics enterprise strategies in response to

consumer complaints. He et al. (37) studied the impact of consumer feedback on green product quality supervision by integrating the feedback channels of consumer online evaluation and complaints. The above research is based mainly on the feedback of consumers' online evaluations and complaints. In "Internet + Community Elderly Care," offline evaluation and return visits are important feedback channels for elderly people. It is of great theoretical significance and practical value to integrate the feedback channels of online-offline evaluation, complaint, and return visits of the elderly and to develop an omnichannel feedback mechanism for the elderly.

In summary, most research is focused mainly on the concept, demand, technology, and model of community elderly care, with inadequate attention paid to the regulation of the service quality of "Internet + Community Elderly Care," especially the elderly people's participation in the supervision system of elderly care services. In the process of the "Internet + Community Elderly Care" service supply, the elderly are not only the end consumers of services but also play the role of supervisors. Their supervisory role should not be ignored. Therefore, in this study, we used evolutionary game theory and system dynamics to focus on the relationship between the government, providers, platforms, and elderly people, aiming to solve the following two questions: (1) What is the impact of Omni-feedback mechanism on the elderly care service providers and elderly care service information platforms' behavior? (2) What is the impact of government penalties and subsidies on elderly care service providers and elderly care service information platforms' behavior? These findings will help the government better understand the elderly's evaluation behavior and provide beneficial enlightenment for formulating dynamic adjustment penalties and subsidy policies. Based on these reasons, the contributions of the study are proposed in the following three aspects:

(1) The omnichannel feedback mechanism of the elderly in the "Internet + Community Elderly Care" regulatory system is presented. The relationship between the feedback of the elderly and the strategic choices of all players is deeply analyzed.

(2) Some relevant parameters, such as the size of the offline social network, reputation, and service utility, are introduced in the proposed model. Furthermore, the impact of these parameters on the choice of behavior strategies of each player is quantified.

(3) From the perspective of the whole system, a four-party evolutionary game model is constructed, and its corresponding system dynamics model is also proposed. It is conducive to analyzing each player's dynamic behavior, choice, and interaction to obtain more scientific and valuable conclusions.

2. Problem description and assumptions

2.1. Problem description

It is common knowledge that speculative behavior among elderly care service providers has become an important issue that cannot be ignored in "Internet + Community Elderly Care." The omnichannel feedback mechanism of the elderly and the government's regulatory role can inhibit the speculative behavior of elderly care service providers. The omnichannel feedback mechanism includes the online evaluation conducted by the online evaluation system after the elderly purchase services through online channels and the offline evaluation conducted by the social network after the elderly purchase services through offline channels. Moreover, the return visits of the elderly care service information platforms and the complaint behaviors of the elderly are also part of the content of the Omni-feedback mechanism. The government can restrict the behavior of elderly care service providers and elderly care service information platforms through the policy adjustment of regulations, subsidies, and penalties. These policy adjustments can guide the healthy development of the "Internet + Community Elderly Care" industry. The relationships between the various subjects in "Internet + Community Elderly Care" are shown in Figure 1.

2.2. Model assumptions

This study used the evolutionary game as a research method because the regulation of "Internet + Community Elderly Care" services often involves multiple stakeholders with limited rationality, and the strategic choice of each stakeholder is influenced by many factors such as income, cost, and mutual influence. Stakeholders interact with each other through multiple rounds of strategy selection to achieve a stable state of strategy selection, which is the same as the characteristics of evolutionary game theory (EGT) (38). At present, EGT has been successfully applied to various economic and social issues, such as environmental governance (39–42), supply chain collaboration (43, 44), green building development (45, 46), online car-hailing platform regulations (47–49) and elderly service provision (50, 51). Therefore, EGT is more suitable for us to study the regulation of "Internet + Community Elderly Care" services.

The following hypotheses are proposed to construct the four-party evolutionary game model.

Hypothesis 1. Government departments, elderly care service providers, elderly care service information platforms, and elderly people are selected as the subjects of the four-party game. The probability of elderly care service providers offering high-quality (H.Q.) or low-quality service (L.Q.) is $(x, 1 - x)$. The

FIGURE 1
The relationships among the various subjects.
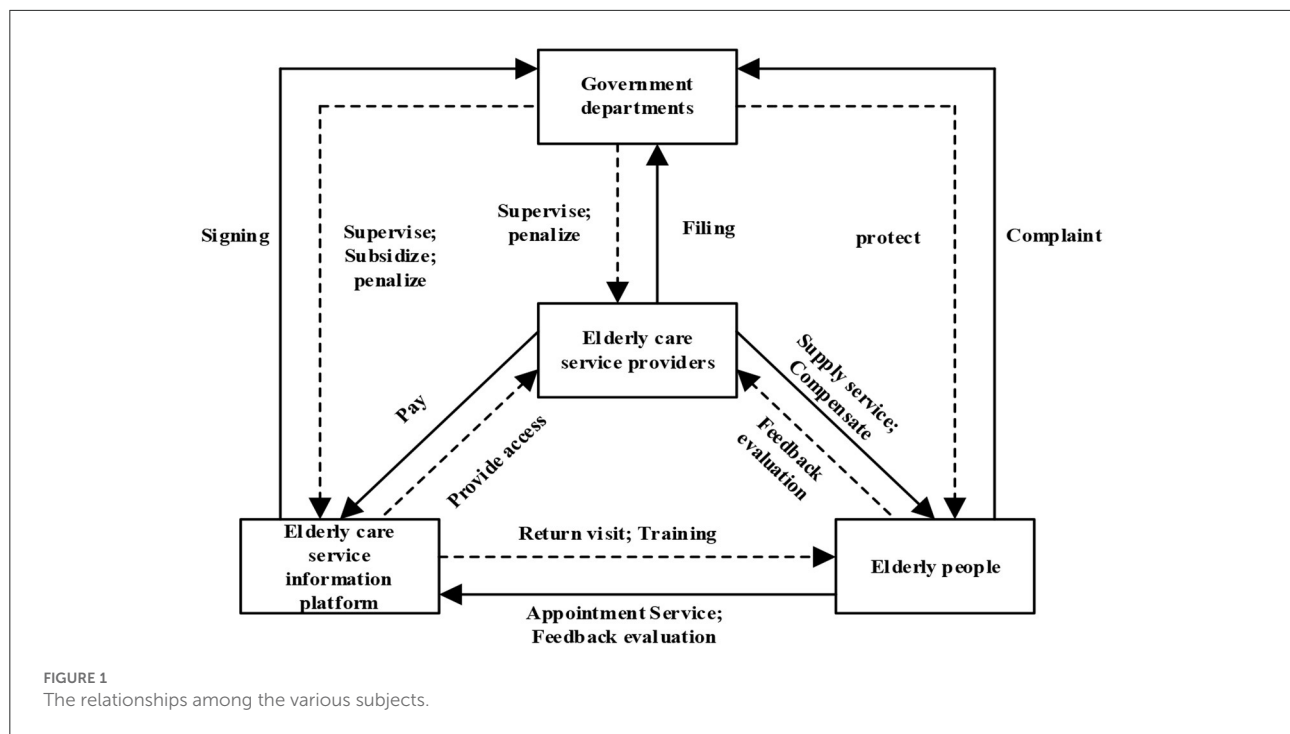
probability of the elderly care service information platforms performing positive return visits (P.V.) or negative return visits (N.V.) is (y, $1 - y$). The probability of government departments enforcing positive regulations (P.R.) or negative regulations (N.R.) is (z, $1 - z$). The probability that elderly people choose online evaluation (ON) or offline evaluation (OF) toward the services they have purchased is (w, $1 - w$). Here, $x, y, z, w \in [0, 1]$.

Hypothesis 2. The elderly care service providers can earn $(1 - \alpha)Rs$ for services offered through the elderly care service information platforms channel, where Rs is the total revenue of both the elderly care service providers and information platforms, α is the percentage of revenue to the elderly care service information platforms. The cost of providing high-quality service to elderly people is Csh, and the cost of providing low-quality service is $Csl(Csh > Csl)$. When the elderly care service providers provide low-quality services, they will be subjected to administrative penalties from the government and are required to compensate the elderly who purchased the service for Io.

Hypothesis 3. The elderly care service information platforms make return visits to customers who purchase and use elderly care services at the cost of Cei. When the elderly care service providers publish their service information through the elderly care service information platforms, elderly care service information platforms will collect αRs as commission income. The operating cost of the elderly care service information platforms is Ceo. When the elderly care service information platforms return positively, they will receive operating subsidies S from government departments. When the elderly care service

information platforms return negatively and the elderly care service providers are confirmed to be providing low-quality services, they will be fined Fe by the government.

Hypothesis 4. The cost of positive regulations by the government is Cg. When the government imposes regulations negatively, the elderly may file a complaint, which may result in the government being fined by its superior government with penalties Fg. When offering high-quality services, elderly care service providers will produce social welfare Rg. When providing low-quality services, elderly care service providers may hurt the interests and even the health of the elderly. It would disrupt the development of the "Internet + Community Elderly Care" industry and cause social loss Dg.

Hypothesis 5. When providing online evaluations, the elderly will make some effort, such as learning the software for making appointments, evaluating, and spending some time, which costs Cw. On the other hand, offline evaluations incur Cm for the use of a smart terminal calling device such as a push-to-talk or phone. The elderly care service providers provide high-quality services that will bring physical and mental pleasure to the elderly, generating gainful utility Ro. On the contrary, the low-quality services provided by elderly care service providers will cause financial, physical, and mental damage Do to elderly people. When their rights are violated, the elderly may have a certain probability of complaining to the relevant government to safeguard their rights, with a rate of β, $\beta \in [0, 1]$, and a cost of Co.

Hypothesis 6. The size of the offline social network for elderly people is $\gamma \in [0, 1]$, which indicates the proportion of the potential customer affected by offline evaluations compared

to the potential customer affected by online evaluations. In the omnichannel feedback mechanism, the elderly care service providers who provide high-quality services will gain the trust of elderly people and their families. They may gain more new clients and then have a reputational gain Is. The elderly care service providers who offer low-quality services will suffer reputational losses Ds due to damage to their reputation and loss of market share. Similarly, positive return visits by the elderly care service information platforms will promote reputational gains Ie, while negative ones will cause reputational losses De.

3. Stability analysis of players' strategy choices

Based on Hypotheses 1–5 in Section 2, a game payment matrix of the government, elderly care service providers, elderly care service information platforms, and the elderly are constructed under different strategy choices, which are shown in Table 1.

3.1. Stability analysis for elderly care service providers

It follows from the game payment matrix that the expected revenue of the elderly care service providers who choose to provide high-quality services (low-quality services) is $Ux(U_{1-x})$, and the average expected revenue of the elderly care service providers is $\bar{U}x$:

$$Ux = (1-\alpha)Rs - Csh + wIs + (1-w)Is\gamma \qquad (1)$$

$$U_{1-x} = (1-\alpha)Rs - Csl - wDs - (1-w)Ds\gamma - zFs$$
$$- yIo - (1-y)zIo - (1-y)(1-z)(\beta Fs + \beta Io) \qquad (2)$$

$$\bar{U}x = xUx + (1-x)U_{1-x} \qquad (3)$$

By using the Malthusian equation, the replicator dynamic equation and the first-order derivative of the elderly care service providers can be written as follows:

$$F(x) = dx/dt = x(Ux - \bar{U}x) = x(1-x)G(y,z,w) \qquad (4)$$

$$F'(x) = (1-2x)G(y,z,w) \qquad (5)$$

$$G(y,z,w) = w(1-\gamma)(I_s + D_s) + zFs + C_{sl} - C_{sh} + I_s\gamma + D_s\gamma$$
$$+ yI_o + (1-y)zI_o + (1-y)(1-z)(\beta Fs + \beta I_o)$$
$$(6)$$

The dynamic replicator equation shows that some factors influence the service provision of elderly care service providers, such as the strategic choice of other players and all other factors

that are closely related to the cost-benefit of the elderly care service providers. Using the stability theorem of the differential equation, the probability of decision-making of the elderly care service providers in a stable state must satisfy $F(x) = 0$ and $F'(x) < 0$.

Proposition 1. When $w > w_0$, elderly care service providers provide a high-quality service. When $w < w_0$, elderly care service providers provide low-quality service. When $w = w_0$, its stabilization strategy cannot be determined. The threshold w_0 is defined as follows:

$$w_o = \{C_{sh} - C_{sl} - I_s\gamma - D_s\gamma - zF_s - yI_o - (1-y)[(1-z)(\beta F_s$$
$$+ \beta I_o) + z_o I]\}/(1-y)(I_s + D_s).$$

Proof of Proposition 1. Because $\partial G(y,z,w)/\partial w > 0$ $G(y,z,w)$ is an increasing function of w. When $w < w_0$, we have that $G(y,z,w) < 0$, $F(x)|_{x=0} = 0$, $F'(x)|_{x=0} < 0$, and then $x = 0$ has stability. When $w > w_0$, $G(y,z,w) > 0$, $F(x)|_{x=1} = 0$, $F'(x)|_{x=1} < 0$, and then $x = 1$ has stability. When $w = w_0$, $G(y,z,w) = 0$, $F(x) = 0$ and $F'(x) = 0$, which cannot determine a stable strategy. The proof of Proposition 1 is complete.

Proposition 1 suggests that an increase in the probability of online evaluations by elderly people would lead to a shift in the stabilization strategy of elderly care service providers from providing low-quality services to supplying high-quality services. However, an increase in the proportion of offline evaluations by elderly people will make the elderly care service providers take risks and eventually choose to provide low-quality services. This implies that the online evaluation behavior of elderly people can be an effective deterrent to the supply of low-quality services by elderly service providers. The elderly should be motivated to take the initiative and actively learn how to operate the software for elderly services.

From Proposition 1, the evolutionary trajectory of elderly care service providers' strategies is obtained, as shown in Figure 2.

From Figure 2, the volume of part $Vx0$ is the probability that the elderly care service providers will choose to provide low-quality services. The volume of part $Vx1$ is the probability that it will supply high-quality services. Let $a = Csh - Csl - Is\gamma - Ds\gamma - yIo - \beta(1-y)(Fs+Io)$ and $b = (1-y)(\beta Fs + \beta Io - Io) - Fs$. Then $w_0 = (a+bz)/(1-\gamma)(Is+Ds)$, it is easy to obtain the following:

$$Vx0 = \int_0^1 \int_0^1 (a+bz)/(1-\gamma)(I_s+D_s)dzdx$$
$$= (2a+b)/2(1-\gamma)(I_s+D_s) \qquad (7)$$

$$Vx1 = 1 - Vx0 = 1 - (2a+b)/2(1-\gamma)(Is+Ds) \qquad (8)$$

Corollary 1.1. The elderly care service providers will be more inclined to provide low-quality services when there is an increase in cost shrinkage arising from the provision of low-quality services. On the contrary, when reputational gains or losses increase, or when penalties for illegal acts of the elderly

TABLE 1 Payment matrix for the players.

Elderly care service information platforms			Government			
			PR (z)		NR (1 − z)	
Elderly people			ON (w)	OF (1 − w)	ON (w)	OF (1 − w)
Elderly care service providers	HQ (x)	PV (y)	$(1-\alpha)Rs - Csh + Is,$ $\alpha Rs - Cei - Ceo + S + Ie,$ $Rg - Cg - S, Ro - Cw$	$(1-\alpha)Rs - Csh + Is\gamma,$ $\alpha Rs - Cei - Ceo + S + Ie\gamma, Rg - Cg - S,$ $Ro - Cm$	$(1-\alpha)Rs - Csh + Is,$ $\alpha Rs - Cei - Ceo + S + Ie,$ $Rg - S, Ro - Cw$	$(1-\alpha)Rs - Csh + Is\gamma,$ $\alpha Rs - Cei - Ceo + S + Ie\gamma, Rg - S, Ro - Cm$
		NV (1 − y)	$(1-\alpha)Rs - Csh + Is,$ $\alpha Rs - Ceo - De,$ $Rg - Cg, Ro - Cw$	$(1-\alpha)Rs - Csh + Is\gamma,$ $\alpha Rs - Ceo - De\gamma,$ $Rg - Cg, Ro - Cm$	$(1-\alpha)Rs - Csh + Is,$ $\alpha Rs - Ceo - De, Rg,$ $Ro - Cw$	$(1-\alpha)Rs - Csh + Is\gamma,$ $\alpha Rs - Ceo - De\gamma, Rg,$ $Ro - Cm$
	LQ (1 − x)	PV (y)	$(1-\alpha)Rs - Csl - Io -$ $Fs - Ds,$ $\alpha Rs - Cei - Ceo + S + Ie,$ $Fs - S - Cg - Dg,$ $Io - Cw - Do$	$(1-\alpha)Rs - Csl - Io -$ $Fs - Ds\gamma, \alpha Rs - Cei -$ $Ceo + S + Ie\gamma,$ $Fs - S - Cg - Dg,$ $Io - Cm - Do$	$(1-\alpha)Rs - Csl - Ds - Io,$ $\alpha Rs - Cei - Ceo + S + Ie,$ $-S - Dg,$ $Io - Cw - Do$	$(1-\alpha)Rs - Csl -$ $Ds\gamma - Io, \alpha Rs - Cei -$ $Ceo + S + Ie\gamma,$ $-S - Dg,$ $Io - Cm - Do$
		NV(1 − y)	$(1-\alpha)Rs - Csl - Io -$ $Fs - Ds,$ $\alpha Rs - Ceo - Fe - De,$ $Fs + Fe - Cg - Dg,$ $Io - Cw - Do$	$(1-\alpha)Rs - Csl - Io -$ $Fs - Ds\gamma,$ $\alpha Rs - Ceo - Fe - De\gamma,$ $Fs + Fe - Cg - Dg,$ $Io - Cm - Do$	$(1-\alpha)Rs - Csl -$ $\beta Fs - Ds - \beta Io,$ $\alpha Rs - Ceo - \beta Fe - De,$ $\beta(Fs + Fe - Fg) - Dg,$ $\beta(Io - Co) - Cw - Do$	$(1-\alpha)Rs - Csl -$ $\beta Fs - Ds\gamma - \beta Io,$ $\alpha Rs - Ceo - \beta Fe - De\gamma,$ $\beta(Fs + Fe - Fg) - Dg,$ $\beta(Io - Co) - Cm - Do$

FIGURE 2
The evolutionary trajectory of elderly care service providers' strategy.
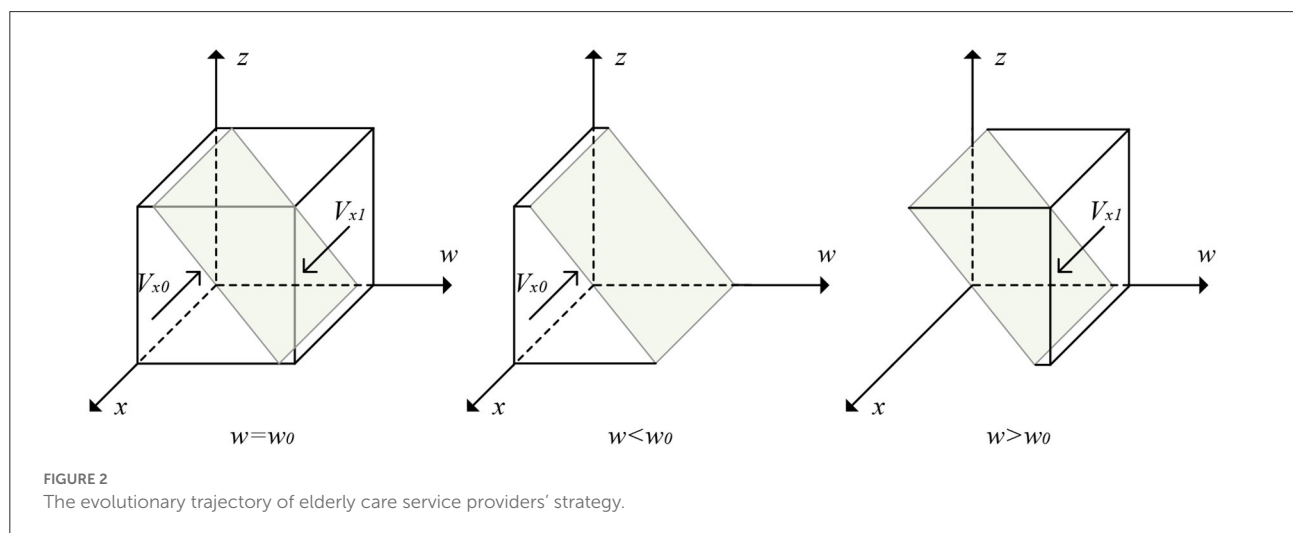
care service platforms increase, the elderly care service providers will be more inclined to provide high-quality services.

Proof of Corollary 1.1. The first order derivative from $Vx1$ for $Csh - Csl, Is, Ds, Fs$, respectively, gives the following:

$$\partial Vx1/\partial(Csh - Csl) = -1/(1 - \gamma)(Is + Ds) < 0,$$

$$\partial Vx1/\partial Is = [\gamma(1 - \gamma)(Is + Ds) + (1 - \gamma)(2a + b)]$$
$$/2(1 - \gamma)^2(Is + Ds)^2 > 0,$$

$$\partial Vx1/\partial Ds = [\gamma(1 - \gamma)(Is + Ds) + (1 - \gamma)(2a + b)]$$
$$/2(1 - \gamma)^2(Is + Ds)^2 > 0,$$

$$\partial Vx1/\partial Fs = (2\beta - 2\beta y - \beta z + \beta yz + z)$$
$$/2(1 - \gamma)(Is + Ds) > 0.$$

The proof of Corollary 1.1 is complete.

Corollary 1.2. Government should impose penalties Fs greater than a certain threshold $F's$ to ensure that elderly care service providers provide high-quality services. The following scenarios may occur. For example, the gains of low-quality services in illegal increase; the reputational gains and losses decrease; the likelihood of online evaluation decline; the size of offline social networks decreases; compensations decrease; and the number of complaints from elderly people decreases. Under these scenarios, the government needs to increase fines. Here,

the threshold $F's$ is defined as follows:

$$F's = \{Csh - Csl - w(1 - \gamma)(Is + Ds) - Is\gamma - Ds\gamma - yIo$$
$$- (1 - y)[(1 - z)\beta Io + zIo]\}/[z + (1 - y)(1 - z)\beta].$$

Proof of Corollary 1.2. It follows from $F'(x)|_{x=1} < 0$ and Proposition 1 that $Fs > F's$. By calculating the first-order partial derivative of $Csh - Csl$, Is, Ds, w, γ, Io, and β for $F's$, respectively, it is easy to conclude that $\partial F's/\partial(Csh - Csl) > 0$, $\partial F's/\partial Is < 0$, $\partial F's/\partial Ds < 0$, $\partial F's/\partial w < 0$, $\partial F's/\partial \gamma < 0$, $\partial F's/\partial Io < 0$ and $\partial F's/\partial\beta < 0$. Therefore, $F's$ is positively correlated with $Csh - Csl$ and negatively correlated with Is, Ds, w, γ, Io and β, respectively. The proof of Corollary 1.2 is complete.

3.2. Stability analysis for elderly care service information platforms

The expected revenue for the positive return visit (negative return visit) strategy chosen by the elderly care service information platforms is $Uy(U_{1-y})$, and its average expected revenue is $\bar{U}y$:

$$Uy = \alpha Rs - Ceo - Cei + wIe + (1 - w)Ie\gamma + S \quad (9)$$

$$U_{1-y} = \alpha Rs - Ceo - wDe - (1 - w)De\gamma$$
$$- (1 - x)[zFe + (1 - z)\beta Fe] \quad (10)$$

$$\bar{U}y = yUy + (1 - y)U_{1-y} \quad (11)$$

The replicator dynamic equation and first-order derivative of the elderly care service information platforms can be calculated as follows:

$$F(y) = dy/dt = y(Uy - \bar{U}y) = y(1 - y)H(x, z, w) \quad (12)$$

$$F'(y) = (1 - 2y)H(x, z, w) \quad (13)$$

$$H(x, z, w) = w(1 - \gamma)(Ie + De) + Ie\gamma + De\gamma$$
$$+ S - Cei + (1 - x)[zFe + (1 - z)\beta Fe] \quad (14)$$

From Equations 12–14, it can be seen that the strategy of the elderly care service information platforms mainly depends on the choices of the three remaining parties, the strength of the government penalties or subsidies, and the size of reputational gains and losses. By using the stability theorem of a differential equation, the decision probability of the elderly care service information platforms in a stable state must satisfy $F(y) = 0$ and $F'(y) < 0$.

Proposition 2. When $w > w_1$, the elderly care service information platforms choose positive return visits. When $w <$ w_1, the elderly care service information platforms will choose negative return visits. When $w = w_1$, its stabilization strategy cannot be determined. The threshold $w1$ is defined as follows:

$$w_1 = \{Cei - S - Ie\gamma - De\gamma$$
$$- (1 - x)[zFe + (1 - z)\beta Fe]\}/(1 - \gamma)(Ie + De).$$

Proof of Proposition 2. Since $\partial H(x, z, w)/\partial w > 0$, $H(x, z, w)$ is an increasing function with regard to w. When $w < w_1$, we have that $H(x, z, w) < 0$, $F(y)|_{y=0} = 0$, $F'(y)|_{y=0} < 0$, and then $y = 0$ has stability. When $w > w_1$, $H(x, z, w) > 0$, $F(y)|_{y=1} = 0$, $F'(y)|_{y=1} < 0$, and then $y = 1$ has stability. When $w = w_1$, we can obtain that $H(x, z, w) = 0$, and then $F(y) = 0$ and $F'(y) = 0$. Now, no stable strategy can be identified. The proof of Proposition 2 is complete.

It follows from Proposition 2 that an increase in the probability of online evaluation by elderly people will make the elderly care service information platforms more inclined to choose positive return visits. In contrast, an increase in the proportion of elderly people who evaluate offline will reduce both the possible reputational gains and losses faced by elderly care service information platforms. With the lower self-regulatory business gains and higher speculative business gains, the strategy of elderly care service information platforms will shift from positive return visits to negative return visits.

From Proposition 2, the evolutionary trajectory of elderly care service information platforms' strategy is obtained, as shown in Figure 3.

Figure 3 shows the volumes of parts $Vy0$ and $Vy1$ are the probabilities of the elderly care service information platforms choosing negative return visits and positive return visits, respectively. Let $c = Cei - S - Ie\gamma - De\gamma$ and $d = zFe + (1-z)\beta Fe$. Then, $w_1 = (c - d + dx)/(1 - \gamma)(Ie + De)$, and we have the following equation:

$$Vy0 = \int_0^1 \int_0^1 (c - d + dx)/(1 - \gamma)(Ie + De)dxdy$$
$$= (2c - d)/2(1 - \gamma)(Ie + De) \quad (15)$$

$$Vy1 = 1 - Vy0 = 1 - (2c - d)/2(1 - \gamma)(Ie + De) \quad (16)$$

Corollary 2.1. When the cost of positive return visits by elderly care service information platforms increases, those platforms will be more inclined to a negative return visit. When reputational gains or losses increase, the complaint rate of elderly people increases, the government imposes penalties, and the elderly care service information platforms will be more inclined to make positive return visits.

Proof of Corollary 2.1. The first order derivative from $Vy1$ for Cei, β, Ie, De and Fe, respectively, gives $\partial Vy1/\partial Cei < 0$, $\partial Vy1/\partial\beta > 0$, $\partial Vy1/\partial Ie > 0$, $\partial Vy1/\partial De > 0$, $\partial Vy1/\partial Fe > 0$. The proof of Corollary 2.1 is complete.

FIGURE 3
The evolutionary trajectory of elderly care service information platforms' strategy.
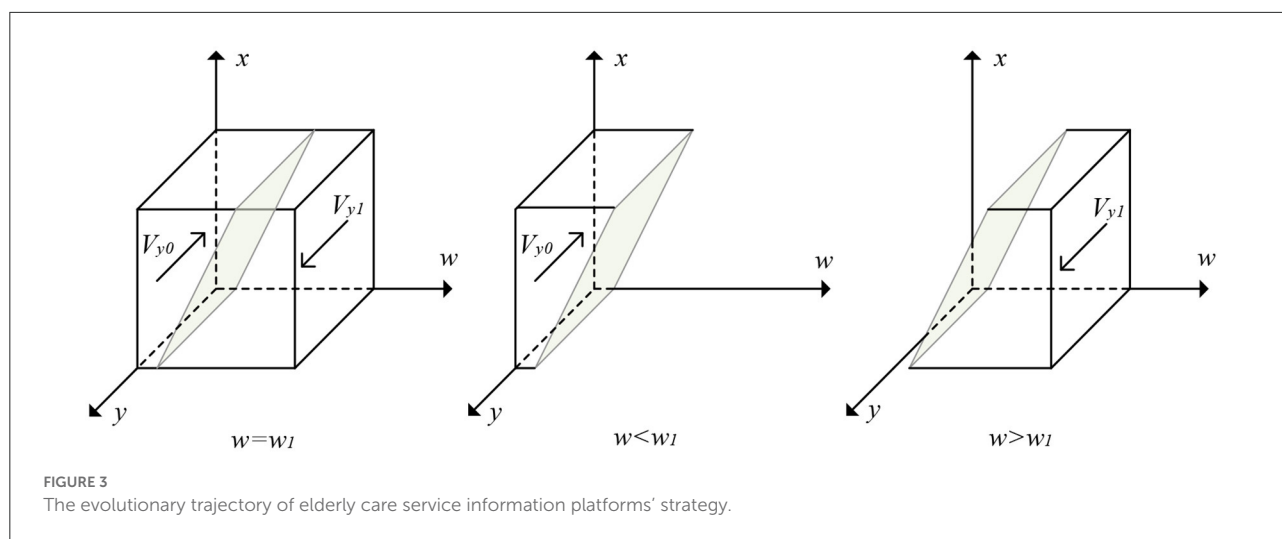
Corollary 2.2. The government subsidies S to the elderly care service information platforms should be greater than a certain threshold S' to effectively use these platforms. When some issues emerge, the government should increase policy subsidies for elderly care service information platforms. These scenarios include an increase in the cost of return visits, a decrease in the probability of online evaluations, a decrease in reputational gains and losses, a decrease in the size of offline social networks, an increase in the probability of providing high-quality services, a decrease in the intensity of government supervision and punishment, and a decrease in the complaint rate among the elderly. Here, the threshold S' is defined as follows:

$$S' = Cei - Ie\gamma - De\gamma - w(1-\gamma)(Ie + De)$$
$$- (1-x)[zFe + (1-z)\beta Fe].$$

Proof of Corollary 2.2. It follows from $F'(y)|_{y=1} < 0$ and Proposition 2 that, $S > S'$. It can be easily observed from the first order partial derivative of Cei, w, Ie, De, γ, x, z, Fe, and β for S' that $\partial S'/\partial Cei > 0$, $\partial S'/\partial w < 0$, $\partial S'/\partial Ie < 0$, $\partial S'/\partial De < 0$, $\partial S'/\partial \gamma < 0$, $\partial S'/\partial x > 0$, $\partial S'/\partial z < 0$, $\partial S'/\partial Fe < 0$, and $\partial S'/\partial \beta < 0$, respectively. Thus, S' is positively correlated with Cei and x, and negatively correlated with w, Ie, De, γ, z, Fe, and β. The proof of Corollary 2.2 is complete.

3.3. Stability analysis for government

The expected revenue for the positive regulation (negative regulation) strategy implemented by the government is $Uz(U_{1-z})$, and its average expected revenue is $\bar{U}z$:

$$Uz = xRg - yS - Cg + (1-x)[Fs - Dg + (1-y)Fe] \quad (17)$$

$$U_{1-z} = xRg - yS + (1-x)[(1-y)\beta(Fs + Fe - Fg) - Dg] \quad (18)$$

$$\bar{U}z = zUz + (1-z)U_{1-z} \quad (19)$$

The replicator dynamic equation and first-order derivative of government can be formulated as follows:

$$F(z) = dz/dt = z(Uz - \bar{U}z) = z(1-z)P(x,y) \quad (20)$$

$$F'(z) = (1-2z)P(x,y) \quad (21)$$

$$P(x,y) = (1-x)[Fs + (1-y)Fe - (1-y)\beta(Fs + Fe - Fg)]$$
$$- Cg \quad (22)$$

It can be seen from Equations 20–22 that the government's strategic choice is influenced by that of the elderly care service providers and the elderly care service information platforms, as well as revenue and expenditure from various government departments. By using the stability theorem of the differential equation, the decision probability of government in a stable state must satisfy $F(z) = 0$ and $F'(z) < 0$.

Proposition 3. When $x > x_0$, the government enforces negative regulations. When $x < x_0$, the government enforces positive regulations. When $x = x_0$, the stabilization strategy of the government cannot be determined. Here, the threshold is defined as follows:

$$x_0 = [Fs + (1-y)(Fe - \beta Fs - \beta Fe + \beta Fg) - Cg]$$
$$/[Fs + (1-y)(Fe - \beta Fs - \beta Fe + \beta Fg)].$$

Proof of Proposition 3. Because $\partial P(x,y)/\partial x < 0$, $P(x,y)$ is a decreasing function about x. When $x > x_0$, we have that

$P(x, y) < 0$, $F(z)|_{z=0} = 0$, $F'(z)|_{z=0} < 0$, and then $z = 0$ has stability. When $x < x_0$, it follows that $P(x, y) > 0$, $F(z)|_{z=1} = 0$, $F'(z)|_{z=1} < 0$, and then $z = 1$ has stability. When $x = x_0$, $P(x, y) = 0$, $F(z) = 0$ and $F'(z) = 0$, which cannot determine a stable strategy. The proof of Proposition 3 is complete.

Proposition 3 suggests that if the elderly care service providers provide high-quality services, the cost of positive regulations by government departments is not equal to the benefit. Thus, the government will switch from positive to negative regulations. When elderly care service providers offer low-quality services, the government faces significant social losses and the risk of accountability from higher levels and would prefer a positive regulatory strategy.

From Proposition 3, the evolutionary trajectory of the government's strategy is obtained, as shown in Figure 4.

From Figure 4, we can see that the volumes of parts $Vz0$ and $Vz1$ are the probabilities of the government implementing negative and positive regulations. If we assume $m = Fe - \beta Fs - \beta Fe + \beta Fg$, then $x_0 = 1 - Cg/[Fs + (1-y)m]$, and we have the following equation:

$$Vz1 = \int_0^1 \int_0^1 1 - Cg/[Fs + (1-y)m]dydz$$
$$= 1 - Cg \ln|1 + m/Fs|/m \qquad (23)$$

$$Vz0 = 1 - Vz1 = Cg \ln|1 + m/Fs|/m \qquad (24)$$

Corollary 3.1. The cost of positive regulations by the government negatively affects the probability of positive regulations when $Fg > Fs$. Here, $Fg > Fs$ represents that the administrative penalties imposed by the superior government are greater than the revenue from penalties imposed by the government on the elderly care service providers.

Proof of Corollary 3.1. When $Fg > Fs$, we can see that $m > 0$, such that $Vz1 = 1 - Cg \ln(1 + m/Fs)/m$. Using the first-order derivative, we can obtain that $\partial Vz1/\partial Cg = -\ln(1 + m/Fs)/m < 0$. When $Fg < Fs$, the probability of positive regulations by the government is influenced by a combination of factors, such as the rate of elderly people's complaints, the level of penalties imposed on the elderly service information platforms, and the level of policy subsidies for the elderly service information platforms. In this case, it should be discussed according to the specific situation. The proof of Corollary 3.1 is complete.

Corollary 3.2. If the administrative penalties Fg imposed by the superior government on the junior government are greater than a certain threshold $F'g$, it will choose a positive regulatory strategy. Under some scenarios, the superior government should increase the administrative penalties imposed on the junior government to urge him to regulate positively. These scenarios include an increase in the cost of positive regulations, a decrease in the revenue from penalties, a decrease in the complaint rate among elderly people, an increase in the probability of offering high-quality services, and an increase in positive return visit strategies. Here, the threshold $F'g$ is defined as follows:

$$F'g = \{Cg - (1-x)[Fs + (1-y)(Fe - \beta Fs - \beta Fe)]\}$$
$$/(1-x)(1-y)\beta.$$

Proof of Corollary 3.2. By using Proposition 3 $F'(z)|_{z=1} < 0$, we get $Fg > F'g$. It follows from the first order partial derivative of Cg, Fe, Fs, β, x, and y for $F'g$ that $\partial F'g/\partial Cg > 0$, $\partial F'g/\partial Fe < 0$, $\partial F'g/\partial Fs < 0$, $\partial F'g/\partial \beta < 0$, $\partial F'g/\partial x > 0$, and $\partial F'g/\partial y > 0$, respectively. Thus, $F'g$ is positively correlated with Cg, x and y, and negatively correlated with Fe, Fs and β. The proof of Corollary 3.2 is complete.

3.4. Stability analysis for the elderly

The expected revenue for the online evaluation (offline evaluation) strategy chosen by the elderly is $Uw(U_{1-w})$, and its average expected revenue is $\bar{U}w$:

$$Uw = xRo - Cw + (1-x)[(1-y)zIo + \beta(1-y)(1-z)$$
$$(Io - Co) + yIo - Do] \qquad (25)$$

$$U_{1-w} = xRo - Cm + (1-x)[(1-y)zIo + \beta$$
$$(1-y)(1-z)(Io - Co) + yIo - Do] \qquad (26)$$

$$\bar{U}w = wUw + (1-w)U_{1-w} \qquad (27)$$

The replicator dynamic equation and first-order derivative for elderly people can be formulated as follows:

$$F(w) = dw/dt = w(Uw - \bar{U}w) = w(1-w)(Cm - Cw) \qquad (28)$$

$$F'(w) = (1-2w)(Cm - Cw) \qquad (29)$$

Equations 28 and 29 imply that the strategy of elderly people mainly depends on the cost of online and offline evaluations. Using the stability theorem of the differential equation, the decision probability of the elderly in a steady state must satisfy $F(w) = 0$ and $F'(w) < 0$.

Proposition 4. When the cost of the online evaluation is higher than that of offline evaluations, i.e., $Cm - Cw < 0$, elderly people will choose offline evaluations. When the cost of the online evaluation is lower than that of offline evaluation, i.e., $Cm - Cw > 0$, elderly people will choose online evaluation.

FIGURE 4
The evolutionary trajectory of the government's strategy.
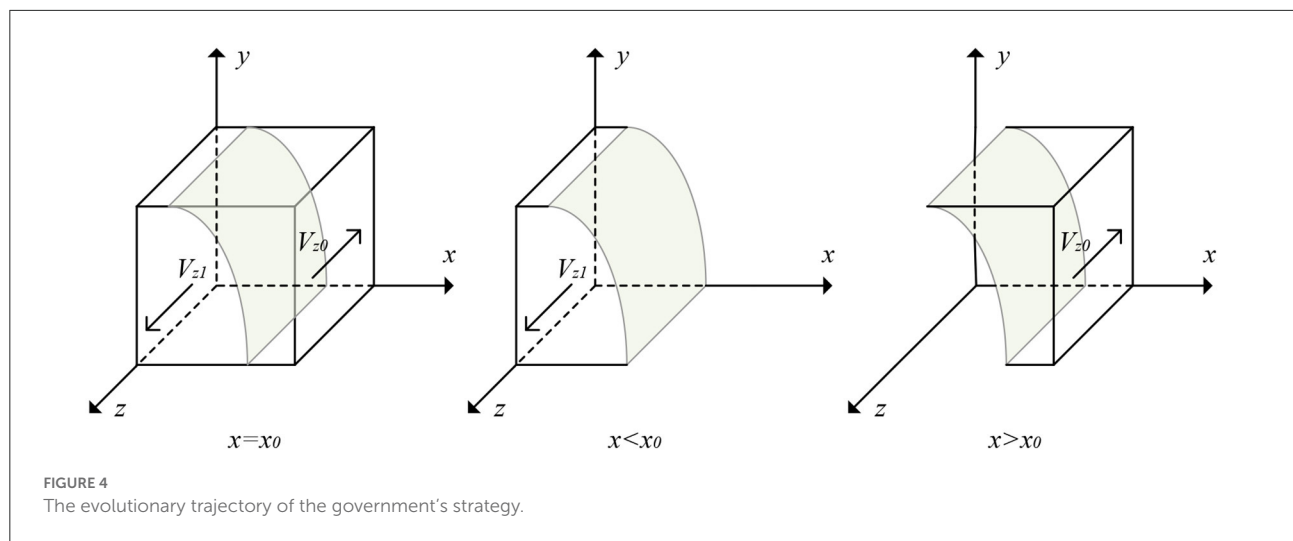
When the cost of the online evaluation is equal to the cost of offline evaluations, i.e., $Cm - Cw = 0$, the stabilization strategy for elderly people cannot be determined.

Proof of Proposition 4. If $Cm - Cw < 0$, then $F(w)|_{w=0} = 0$ and $F'(w)|_{w=0} < 0$. Furthermore, $w = 0$ has stability. If $Cm - Cw > 0$, $F(w)|_{w=1} = 0$ and $F'(w)|_{w=1} < 0$, then $w = 1$ has stability. If $Cm - Cw = 0$, then $F(w) = 0$, $F'(w) = 0$, and no stable strategy for elderly people can be identified. Proposition 4 is complete.

Proposition 4 suggests that the strategy choice of elderly people mainly depends on the cost of offline and online evaluations. Elderly people will always choose the evaluation method with the lowest cost as their optimal strategic choice. Therefore, the government should urge the relevant units to provide the elderly with operation training for software for elderly services. This training would reduce the perceived cost of online evaluations for elderly people and thus encourage them to conduct them.

4. Stability analysis of strategy combinations

To explore the evolutionary stability strategies (ESS) and the conditions that need to be satisfied to reach the corresponding ESS, the stability of the system's strategy combinations needs to be analyzed. As is well known, the stable solution in a multi-group evolutionary game is a strict Nash equilibrium, i.e., a pure strategy equilibrium. Thus, Lyapunov's first method was used to analyze the stability of 16 pure strategy equilibrium points satisfying $F(x) = 0$, $F(y) = 0$, $F(z) = 0$, and $F(w) = 0$. The corresponding Jacobian matrix is stated as follows:

$$J = \begin{bmatrix} \partial F(x)/\partial x & \partial F(x)/\partial y & \partial F(x)/\partial z & \partial F(x)/\partial w \\ \partial F(y)/\partial x & \partial F(y)/\partial y & \partial F(y)/\partial z & \partial F(y)/\partial w \\ \partial F(z)/\partial x & \partial F(z)/\partial y & \partial F(z)/\partial z & \partial F(z)/\partial w \\ \partial F(w)/\partial x & \partial F(w)/\partial y & \partial F(w)/\partial z & \partial F(w)/\partial w \end{bmatrix} \quad (30)$$

4.1. Stability analysis in offline evaluation of elderly people

When the cost of online evaluations for elderly people is higher than that of offline evaluations, there are eight equilibrium points in the replicated dynamic system. The stability analysis of the equilibrium points is shown in Table 2.

It can be seen from Table 2 that there are two instability points when elderly people are evaluated offline. The remaining six equilibrium points can potentially become more stable when certain conditions are met. As the elderly care service providers in the four pure strategy equilibrium points E_1, E_3, E_4, and E_6 all choose to offer low-quality services, these four equilibrium points are then undesirable strategy combinations. Some measures should be taken to improve the reputational gains and losses, the penalties imposed by the government, the complaint rate of elderly people, and the amount of compensation given to elderly people to prevent these points from becoming ESS. Thus, the losses incurred by the elderly care service providers fully cover the cost reduction incurred when they provide low-quality services. For both points E_2 and E_5, the elderly care service providers choose to offer high-quality services. Thus, these two equilibrium points are desirable strategy combinations. When the expected revenue from supplying high-quality services is greater than that from supplying low-quality services, both E_2 and E_5 may become stable points in the system. Specifically, the system will eventually stabilize at E_2 when the sum of the

TABLE 2 Stability analysis in the offline evaluations of elderly people.

Equilibrium point	Eigenvalue $\lambda_1, \lambda_2, \lambda_3, \lambda_4$	Symbol judgment	Stability judgment
$E_1(0,0,0,0)$	$Is\gamma + Csl - Csh - Ds\gamma + \beta Fs + \beta Io,$ $Ie\gamma - Cei + S + De\gamma + \beta Fe,$ $Fs + Fe - \beta Fs - \beta Fe + \beta Fg - Cg,$ $Cm - Cw$	$\times \times \times -$	ESS when $\lambda1 < 0, \lambda2 < 0$ and $\lambda3 < 0$ are satisfied
$E_2(1,0,0,0)$	$Csh - Csl - Is\gamma - Ds\gamma - \beta Fs - \beta Io,$ $Ie\gamma + De\gamma + S - Cei, -Cg, Cm - Cw$	$\times \times - -$	ESS when $\lambda1 < 0$ and $\lambda2 < 0$ are satisfied
$E_3(0,1,0,0)$	$Is\gamma + Csl - Csh + Ds\gamma + Io,$ $Cei - Ie\gamma - De\gamma - S - \beta Fe, Fs - Cg,$ $Cm - Cw$	$\times \times \times -$	ESS when $\lambda1 < 0, \lambda2 < 0$ and $\lambda3 < 0$ are satisfied
$E_4(0,0,1,0)$	$Is\gamma + Fs + Csl - Csh + Ds\gamma + Io,$ $Ie\gamma - Cei + De\gamma + S + Fe,$ $\beta Fe + \beta Fs + Cg - Fs - Fe - \beta Fg,$ $Cm - Cw$	$\times \times \times -$	ESS when $\lambda1 < 0, \lambda2 < 0$ and $\lambda3 < 0$ are satisfied
$E_5(1,1,0,0)$	$Csh - Csl - Is\gamma - Ds\gamma - Io,$ $Cei - Ie\gamma - De\gamma - S, -Cg, Cm - Cw$	$\times \times - -$	ESS when $\lambda1 < 0$ and $\lambda2 < 0$ are satisfied
$E_6(0,1,1,0)$	$Is\gamma + Fs + Csl - Csh + Ds\gamma + Io,$ $Cei - Ie\gamma - De\gamma - S - Fe, Cg - Fs,$ $Cm - Cw$	$\times \times \times -$	ESS when $\lambda1 < 0, \lambda2 < 0$ and $\lambda3 < 0$ are satisfied
$E_7(1,0,1,0)$	$Csh - Csl - Is\gamma - Ds\gamma - Fs - Io,$ $Ie\gamma - Cei + De\gamma + S, Cg, Cm - Cw$	$\times \times + -$	US
$E_8(1,1,1,0)$	$Csh - Csl - Is\gamma - Ds\gamma - Fs - Io,$ $Cei - Ie\gamma - De\gamma - S, Cg, Cm - Cw$	$\times \times + -$	US

$\times$, Uncertainty of positivity or negativity; $+$, Eigenvalues are positive; $-$, Eigenvalues are negativity; US, Unstable point.

reputational gains and losses and operating subsidies earned by the elderly services information platforms is less than the cost of positive return visits. Conversely, the system will stabilize at E_5.

For points E_2 and E_5, it can be seen that when the elderly care service information platforms choose a negative return visit, the absence of their supervision function will result in insufficient constraints on the elderly care service providers. However, this insufficient constraint may be made up by the penalties imposed by the government on the elderly care service providers when the elderly actively defend their rights. This is the reason a course on legal awareness is offered to elderly people.

4.2. Stability analysis in the online evaluation of elderly people

When the cost of online evaluations for elderly people is lower than that of offline evaluations, i.e., $Cm - Cw > 0$, there might be eight equilibrium points in the replicated dynamic system. The stability analysis of the equilibrium strategy combination is shown in Table 3. As can be seen from Table 3, there are also two unstable points E_{15} and E_{16}, four undesirable equilibrium points E_9, E_{11}, E_{12}, and E_{14} that may

become ESS and two desirable equilibrium points that can become ESS. The analysis process is similar to that of the offline evaluation of elderly people.

By comparing the conditions of the corresponding stability points in the online and offline evaluations, it can be concluded that the online evaluation channel for the elderly can increase the reputation losses and gains of elderly care service providers and elderly care service information platforms. Specifically, compared with offline evaluations, online evaluations make it more difficult for the system to create undesirable stability points and more likely to create desirable stability points. This is due to the fact that, in the case of the online evaluation, an undesirable stability point requires a higher cost reduction for elderly care service providers to reach stability. However, a desirable stability point can be achieved with lower compensation, fewer complaints from elderly people, and fewer penalties imposed by government departments.

Therefore, community-based elderly service centers should be relied upon to train the elderly in the community to operate the software for elderly care services. The positive effects of online evaluations should also be publicized to reduce the perceived cost of online evaluations for elderly people. It is important for the healthy development of "Internet + Community Elderly Care".

TABLE 3 Stability analysis in the online evaluation of elderly people.

Equilibrium point	Eigenvalue $\lambda_1, \lambda_2, \lambda_3, \lambda_4$	Symbol judgment	Stability judgment
$E_9(0, 0, 0, 1)$	$Is + Csl - Csh - Ds + \beta Fs + \beta Io, Ie - Cei + De + S + \beta Fe,$ $Fs + Fe - \beta Fs - \beta Fe + \beta Fg - Cg, Cw - Cm$	$\times \times \times -$	ESS when $\lambda 1 < 0, \lambda 2 < 0$ and $\lambda 3 < 0$ are satisfied
$E_{10}(1, 0, 0, 1)$	$Csh - Csl - Is - Ds - \beta Fs - \beta Io, Ie + De + S - Cei, -Cg,$ $Cw - Cm$	$\times \times - -$	ESS when $\lambda 1 < 0$ and $\lambda 2 < 0$ are satisfied
$E_{11}(0, 1, 0, 1)$	$Is + Csl - Csh + Ds + Io, Cei - Ie - De - S - \beta Fe, Fs - Cg,$ $Cw - Cm$	$\times \times \times -$	ESS when $\lambda 1 < 0, \lambda 2 < 0$ and $\lambda 3 < 0$ are satisfied
$E_{12}(0, 0, 1, 1)$	$Is + Fs + Csl - Csh + Ds + Io, Ie - Cei + De + S + Fe,$ $\beta Fe + \beta Fs + Cg - Fs - Fe - \beta Fg, Cw - Cm$	$\times \times \times -$	ESS when $\lambda 1 < 0, \lambda 2 < 0$ and $\lambda 3 < 0$ are satisfied
$E_{13}(1, 1, 0, 1)$	$Csh - Csl - Is - Ds - Io, Cei - Ie - De - S, -Cg, Cw - Cm$	$\times \times - -$	ESS when $\lambda 1 < 0$ and $\lambda 2 < 0$ are satisfied
$E_{14}(0, 1, 1, 1)$	$Is + Fs + Csl - Csh + Ds + Io, Cei - Ie - De - S - Fe, Cg - Fs,$ $Cw - Cm$	$\times \times \times -$	ESS when $\lambda 1 < 0, \lambda 2 < 0$ and $\lambda 3 < 0$ are satisfied
$E_{15}(1, 0, 1, 1)$	$Csh - Csl - Is - Ds - Fs - Io, Ie + De + S - Cei, Cg, Cw - Cm$	$\times \times + -$	US
$E_{16}(1, 1, 1, 1)$	$Csh - Csl - Is - Ds - Fs - S - Io, Cei - S - Ie - De, Cg, Cw - Cm$	$\times \times + -$	US

$\times$, Uncertainty of positivity or negativity; $+$, Eigenvalues are positive; $-$, Eigenvalues are negativity; US, Unstable point.

5. Simulation and analysis

5.1. System dynamics model construction

System dynamics (52) (S.D.) is often applied to study complex systems and analyze evolutionary trends (53–55). Some authors recently used system dynamics to simulate and analyze evolutionary game problems (56–58). In this study, SD was incorporated into the study of the omnichannel feedback mechanism of elderly people to clearly depict the complex relationships and mechanisms of interaction among the subjects. Moreover, VENSIM 5.6b software was used for simulation analysis of the evolutionary game SD model, which involved government departments, elderly care service providers, elderly care service information platforms, and elderly people's participation. The proposed four-party evolutionary game SD model is shown in Figure 5. It consists of four sub-models: government departments sub-SD Model, elderly care service providers sub-SD Model, elderly care service information platforms sub-SD model and elderly people sub-SD Model. The four state variables, four rate variables, and a set of other intermediate and external variables in the model were determined by the model's construction. Furthermore, the functional relationships in the model were determined by the expectation function and the replicator dynamic equation.

5.2. Parameter setting and simulation analysis

To make the system stable to the ideal stability point, the following three conditions should be satisfied, i.e., $Cw - Cm < 0$,

$Cei - Ie - De < 0$, and $Csh - Csl - Is - Ds - Io < 0$. Combined with the actual situation, the corresponding parameters are set as follows: $Rs = 100$, $Csh = 50$, $Csl = 25$, $Is = 20$, $Ds = 22$, $S = 10$, $Ceo = 15$, $Cei = 5$, $Ie = 10$, $De = 12$, $\alpha = 10\%$, $\beta = 1\%$, $\gamma = 5\%$, $Fs = 20$, $Fe = 5$, $Fg = 200$, $Rg = 40$, $Cg = 10$, $Dg = 40$, $Cm = 10$, $Cw = 8$, $Io = 10$, $Ro = 20$, $Do = 30$, and $Co = 5$. In addition, we assumed that $INITIAL\ TIME = 0$, $FINAL\ TIME = 3$, and $TIME\ STEP = 0.0125$.

5.2.1. Influence of penalties and compensations on elderly care service providers

To explore the effects of Fs and Io on the choice of elderly care service providers, the values of Fs and Io are set to fluctuate up and down by 50% around their initial values, respectively. The simulation results are shown in Figure 6.

From Figures 6A, B, it can be seen that, as the values of Fs and Io increase, the speed of the evolution of elderly care service providers to stable strategies has also increased to varying degrees. The greater the values of Fs and Io, the faster the elderly care service providers stabilize in providing high-quality services. This is due to the fact that the greater the values of Fs and Io, the greater the cost faced by the elderly care service providers for supplying low-quality services. Then, the elderly care service providers will tend to choose a strategy of providing high-quality services. In addition, when the values of Fs and Io change in the same proportion, Fs has an obvious impact on the evolutionary speed of elderly care service providers. With a 50% increase in both values of Fs and Io and the value of Fs by 50%, the elderly care service providers devised stable strategies faster.

On the contrary, with a 50% decrease in both values of Fs and Io, the elderly care service providers devise stable strategies

FIGURE 5
The SD model of "Internet + Community Elderly Care".
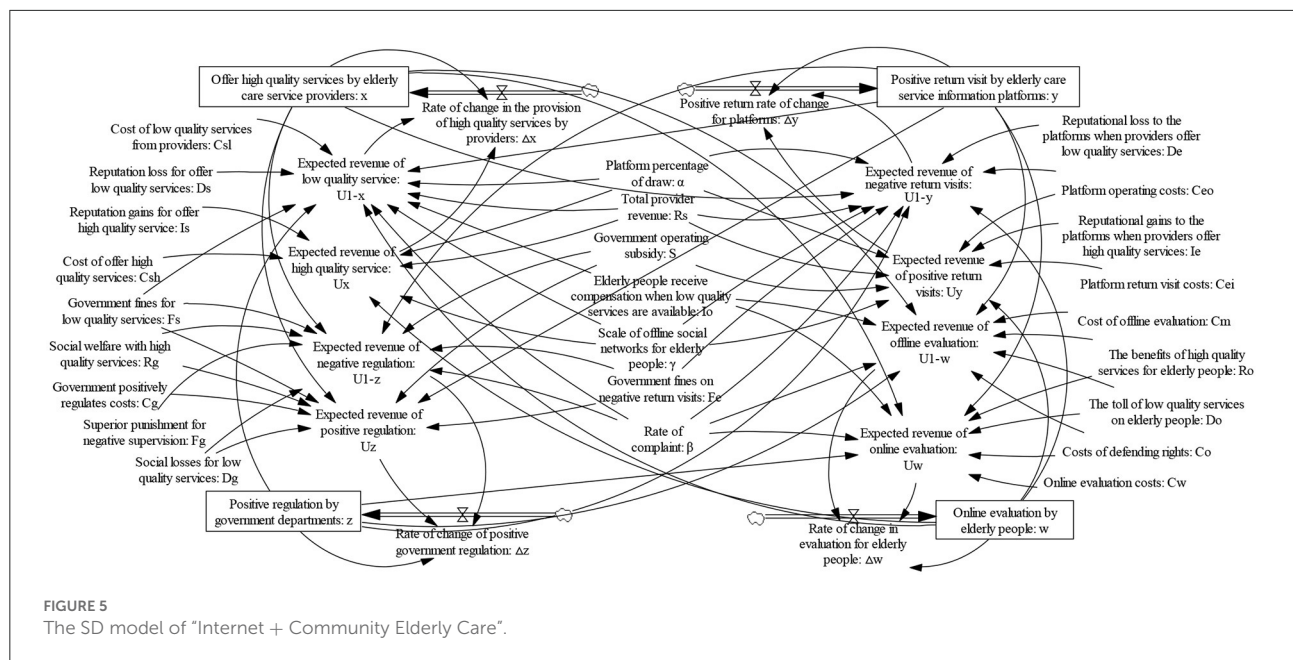
faster with the value of *Io* decrease by 50%. Therefore, elderly care service providers are most sensitive to changes in penalties. Government departments can preferentially adjust *Fs* to guide the healthy development of the elderly market.

care service information platforms by providing subsidies. As a result, the elderly care service information platforms would choose a positive return visit strategy due to the government's adjustment of *S*.

5.2.2. Influence of penalties and subsidies on elderly care service information platforms

To explore the influence of *Fe* and *S* on the choice of strategy for elderly care service information platforms, the values of *Fe* and *S* are set to fluctuate 50% up and down around their initial values, respectively. The simulation results are shown in Figure 7.

As can be seen from Figures 7A, B, changes in both values of *Fe* and *S* will have an impact on the evolutionary speed of the elderly care service information platforms. The greater the values of *Fe* and *S*, the faster the elderly care service information platforms stabilize in a positive return visit strategy. The smaller the values of *Fe* and *S*, the slower the elderly care service information platforms stabilize in a positive return visit strategy. However, the change in the value of *Fe* has little impact on the elderly care service information platforms, while the change in the value of *S* has a more significant impact on the elderly care service information platforms. It is because of this that the negative return visit behavior of the elderly care service information platforms is not illegal. Only when the negative return visit of the elderly care service information platforms makes the elderly care service providers provide low-quality services will the government punish the elderly care service information platforms due to inadequate management. The government encourages the active operation of elderly

5.2.3. Influence of online evaluation on each player

With other initial parameters unchanged, we observed that $w = \{0.25, 0.75\}$. The impact of the proportion of elderly people's online evaluations on the evolution of the decision-making behaviors of the government, elderly care service providers, and elderly care service information platforms is explored. The results are shown in Figure 8.

It can be seen from Figure 8 that with an increase of *w*, elderly care service information platforms and elderly people, evolve to a stable strategy of an active return visit and online evaluation emerged more quickly. At the same time, the evolution of elderly care service providers to provide high-quality services has accelerated due to the positive influence of behavior strategies adopted by elderly people and elderly service information platforms. In this case, the government will relax regulations and the tendency to increase negative regulations will rise. Therefore, online evaluation has a more positive effect on the regulatory system than offline evaluations. Some measures should be taken to increase the proportion of online evaluations of elderly people to promote the positive development of the whole "Internet + Community Elderly Care" system.
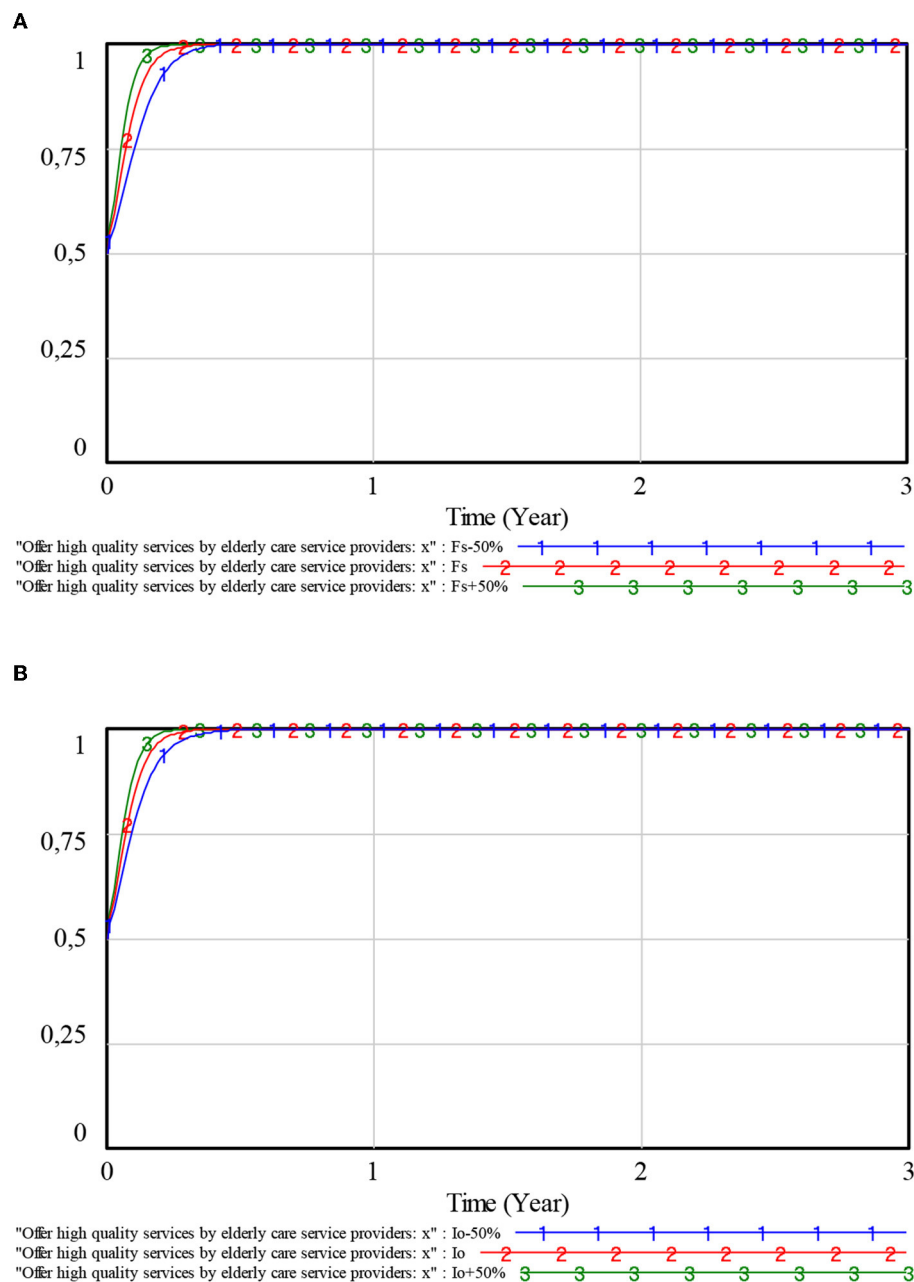
FIGURE 6
Influence of penalties and compensations on elderly care service providers. **(A)** Penalties. **(B)** Compensations.

5.2.4. Influence of reputational gains or losses on each player

To explore the impact of reputational losses and gains on the strategic choice of each player, we allowed the values of I_s, D_s, I_e, and D_e to move up and down by 50% around their initial values. The results are shown in Figure 9.

As can be seen from Figure 9, changes in the values of I_s, D_s, I_e, and D_e have a significant impact on the elderly care

service information platforms, elderly care service providers, and the government. When the values of I_s, D_s, I_e, and D_e are relatively low, the evolutionary speed of the elderly care service information platforms, elderly care service providers, and government to a stable state is relatively slow. With an increase in the values of I_s, D_s, I_e, and D_e, the time to reach a steady state will be shortened for elderly care service providers and elderly care service information platforms.

FIGURE 7
Influence of penalties and subsidies on elderly care service information platforms. **(A)** Penalties. **(B)** Subsidies.

Since the elderly care service information platforms and the elderly care service providers have chosen positive behavior strategies, the government has relaxed the regulations and become faster at imposing regulations. This implies that an effective reputation mechanism can partially replace the government's regulations and reduce the regulatory pressure on the government. Therefore, establishing an effective reputation mechanism will be critical for the development of "Internet + Community Elderly Care."

5.2.5. Influence of complaint rate on each player

With the complaint rate β of the elderly being {0.01, 0.41}, the evolution of the decision-making behaviors of each player was explored. The simulation results are shown in Figure 10.

As can be seen in Figure 10, a change in the complaint rate β of elderly people has an impact on the strategic choices of elderly care service providers and government departments. However, there is essentially no impact on the strategic choices

FIGURE 8
Influence of online evaluation on each player. **(A)** Online evaluation ratio 0.25. **(B)** Online evaluation ratio 0.75.

of elderly care service information platforms and elderly people. For the government, the higher the complaint rate β, the greater the fluctuation of their strategic choice toward positive regulations and the slower the evolution of their strategic choice toward negative regulations. For elderly care service providers, the higher the complaint rate β, the higher the possibility of providing high-quality services consistently. These suggest that complaints from elderly people can encourage both the government and elderly care service providers to choose positive

behavioral strategies because there is a higher probability of being penalized. Therefore, it is vital to raise awareness about complaints and the rights of elderly people.

6. Discussions

This study presented an evolutionary game model to discuss "Internet + Community Elderly Care." The stability of each
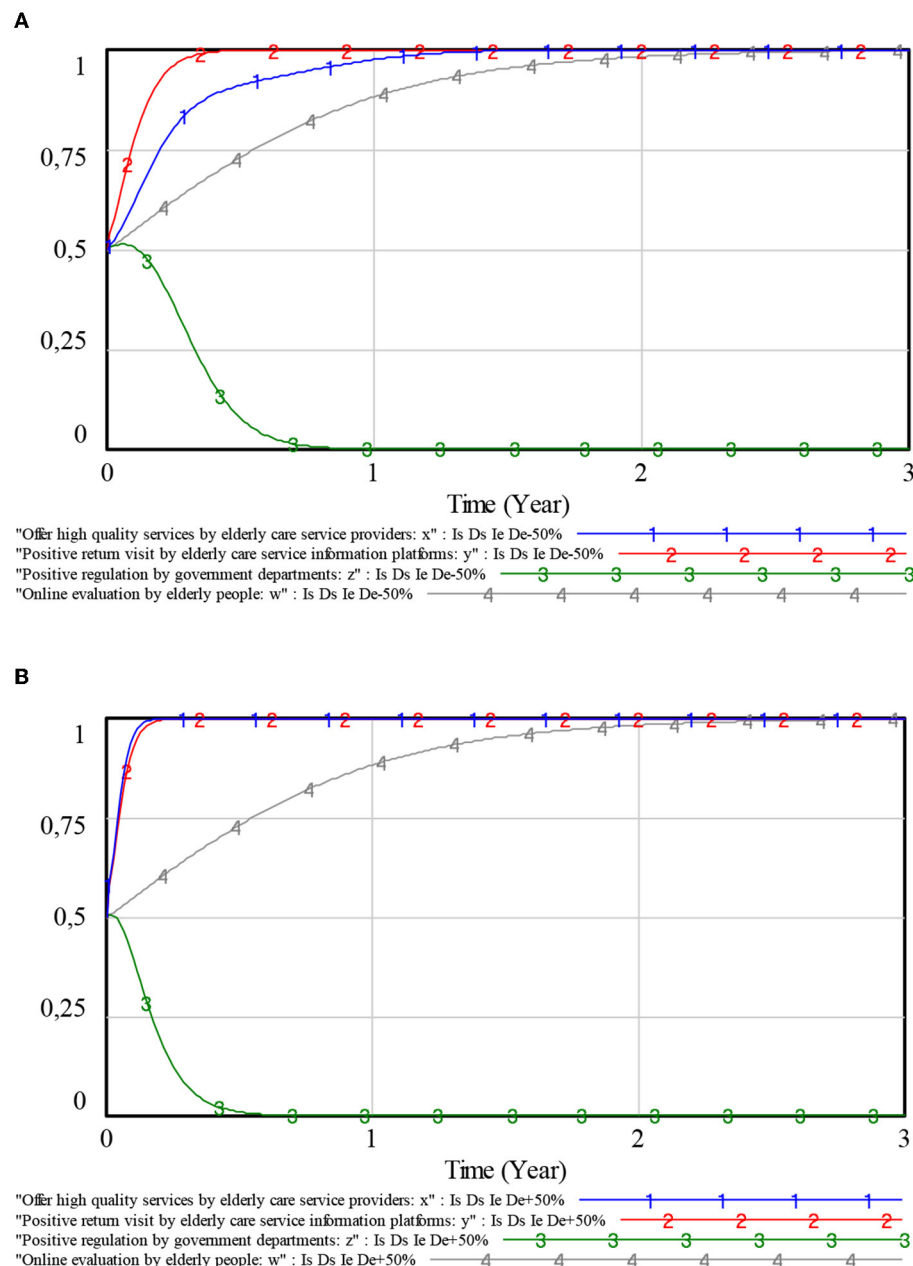
FIGURE 9
Influence of reputational gains or losses on each player. **(A)** Reputation gains or losses moved down by 50%. **(B)** Reputation gains or losses moved up by 50%.

player's strategy and the stability conditions of the replicated dynamic system's strategy combination were analyzed. The effects of changes in each key element on the strategic choices of the relevant players were also simulated in conjunction with system dynamics theory. The main suggestions of the study are proposed as follows:

First, online evaluations of elderly people have more positive effects on the regulatory system than offline ones. It is more

difficult for the system to develop an undesirable stability point than a desirable stability point. Moreover, the proportion of elderly people evaluated online is increasing. The elderly care service providers will be more inclined to provide high-quality services, and the elderly care service information platforms will be more inclined to make return visits. Therefore, it is important to expedite the infrastructure construction of "Internet + Community Elderly Care." However, elderly people need to be
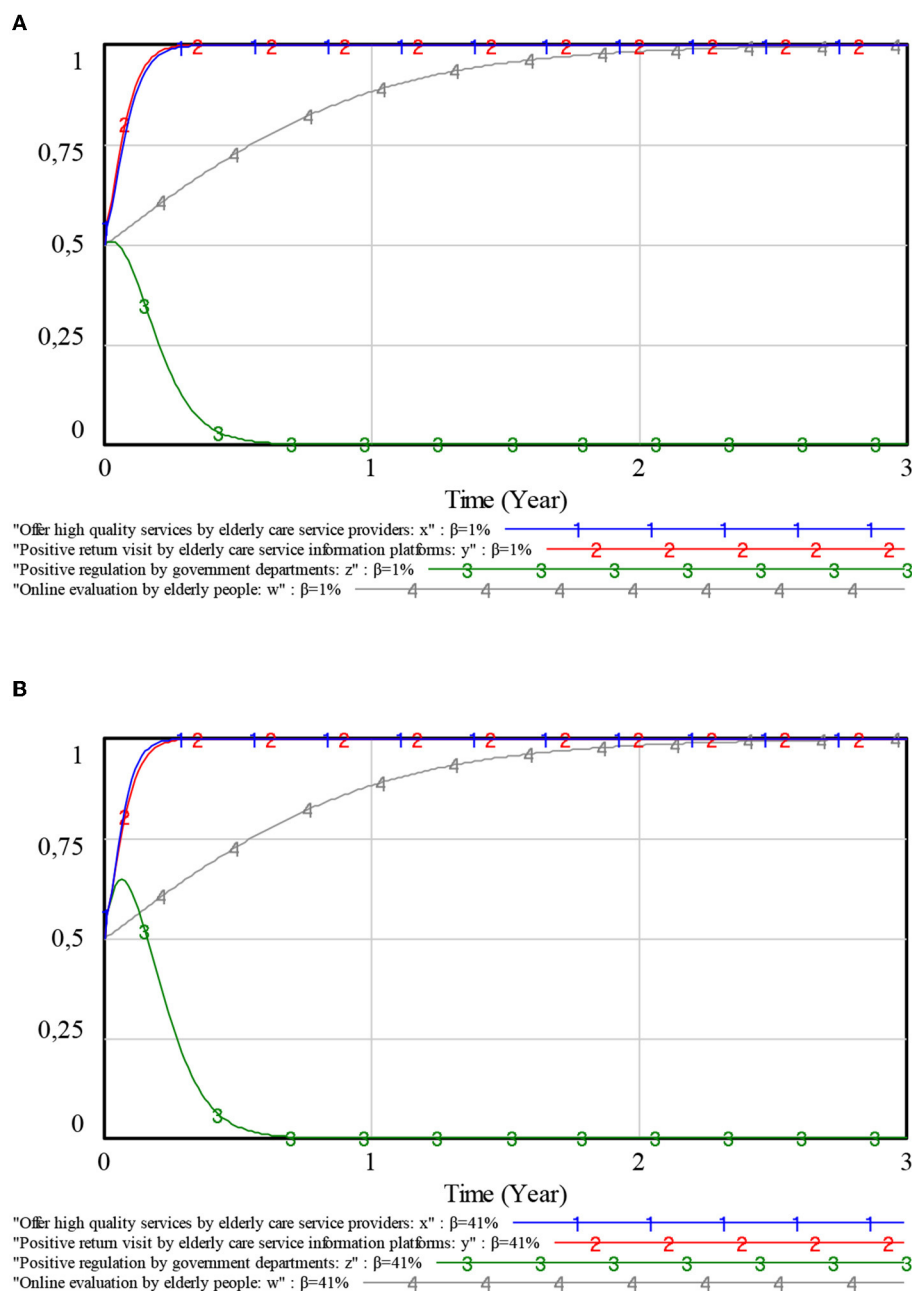
FIGURE 10
Influence of complaint rate on each player. **(A)** Complaint rate 0.01. **(B)** Complaint rate 0.41.

trained. The goal is to ultimately reduce the perceived cost of online evaluation for elderly people.

Second, the Omni-feedback mechanism for elderly people can effectively curtail the speculative behavior of elderly care service providers and elderly care service information platforms. It includes platform return visits, elderly people's online-offline evaluations, and complaint behaviors. Legal awareness seminars for elderly people can raise awareness of the elderly

people's online and offline evaluations and complaint behaviors. Subsidized phone bills, training, and green channels for elderly people can reduce the cost of evaluations and complaints. Media participation or platform publicity can also improve the influence of feedback from elderly people. These measures can enhance the feedback mechanism for elderly people.

Finally, there are thresholds for the government to punish the elderly care service providers and subsidize the elderly

care service information platforms. Only when those thresholds are reached can the government's punishment and subsidy policies be effective. The government should design the level of penalties imposed on the elderly care service providers with reference to their cost savings, reputational gains and losses, level of compensation, and complaint rate. More importantly, the government should dynamically adjust penalties. Similarly, the government can appropriately increase the operating subsidies for elderly care service information platforms to guide them in choosing a strategy for positive return visits.

7. Conclusions

The dual identity of the elderly as consumers and supervisors plays an important role in the supervision of the quality of elderly services. To achieve effective supervision of the quality of elderly services, it is important to boost the willingness of the elderly to participate in online evaluations, establish an effective reputation mechanism, and improve the rate of complaints from elderly people. These measures can curtail the speculative behavior of elderly care service providers while also reducing the pressure of supervision by the government. The government prioritizes penalties for elderly care service providers and subsidies for elderly care service information platforms that can effectively guide them. In order to maintain the effectiveness of government regulations, these penalties and subsidies should also be dynamically adjusted based on the actual situation.

Although the results in this study are rational and significant, there are still some limitations to the detailed description of the elderly people's feedback mechanism. Feedback from the elderly is not only differently influenced by the channel of feedback but is also affected by the emotions of the elderly or/and the induced evaluation behavior of the service providers. These influences may distort the content of the elderly people's feedback. Therefore, future research should consider real and distorted evaluations as a strategy for elderly people. Furthermore, elderly people should complain only when they receive real evaluations. Considering the variables of income and the cost of induced evaluations, the trend of behavior evolution and the influencing factors of participants merit further research.

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

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The implementation of "integration of sports and medicine" in China: Its limitation and recommendations for model improvement

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The "integration of sports and medicine" (ISM) under the "Healthy China 2030" strategy can alleviate the contradiction between residents' health needs and medical supply. Under the "Healthy China 2030" strategy, the government-initiated calls and measures for the integration of sports and medical institutions based on the actual region conditions. This article outlines the "Sports-Medical Integration" program implemented in the coastal cities of China's southeast, Suzhou and Shanghai. We described the specific implementation modes and related deficiencies of the ISM, taking Suzhou and Shanghai as examples. Through three policy recommendations, we put forward the idea of promoting the development of a new model of ISM in China.

KEYWORDS

integration of sports and medicine, Healthy China 2030, policy recommendations, Suzhou Model, Shanghai Model, limitations

Introduction

The comprehensive model of sports combined with medical services plays an active role in chronic disease prevention, rehabilitation, and health promotion (1). As early as the 19th century, American health professionals tried to combine sports and medicine, and explored its feasible implementation mode (2). Both sports and medicine serve public health. Sports improve physical function and prevent diseases through exercise; medical services focus on prevention, treatment, and rehabilitation. The proper combination of the two is an effective way to improve public health and promote the recovery of chronic diseases (3). Physical fitness assessment and the health status of medical examinations are cross-referenced to formulate scientific and personalized exercise prescriptions to solve health problems.

At present, China's population is aging, and the incidence of chronic diseases is increasing year by year. Society and the government are facing major public health challenges (4, 5). The government issued policies aimed at improving citizens' health and effectively controlling the development of chronic diseases. The outline of the

"Healthy China 2030" plan and China's Medium- and Long-term Plan for Prevention and Treatment of Chronic Diseases (2017–2025) mentioned that the ISM will be the inevitable trend of serving public health and preventing chronic diseases in the future (6, 7). After the Beijing Olympics, the country's sports industry development goal has gradually shifted from "Olympic medal fever" to promoting public health. The promulgation of policies such as the 13th Five-Year Plan for sports development, the National Human Rights Action Plan of China (2016–2020), and other policies have made it clear that the sports industry has begun to tilt toward national health (6, 8, 9). This has promoted the formation of disease management and health service model combining sports and medicine. The ISM has been elevated to an important way to create a healthy lifestyle for citizens.

The Several Opinions of the State Council on Accelerating the Development of the Sports Industry and Promoting Sports Consumption put forward the task requirements for promoting integrated development such as "promoting the integration of the sports industry and other industries," and "actively expanding business formats, promoting the integration of sports and medicine, and encouraging mutual accommodation" (10). In the outline of the "Healthy China 2030" Plan, "sharing and co-construction" is the strategic theme of building a healthy China (6). The "Healthy China 2030" made a strategic plan for the integration of the sports industry into the health industry, and specifically discussed the themes of developing new forms of health services, cultivating the sports medical rehabilitation industry and actively developing the fitness and leisure sports industry (6). At present, the ISM is facing unprecedented opportunities: a series of policies are issued to point out the direction for the ISM; industrial integration opens a new path for the ISM; people's multi-level and diversified health needs provide an impetus for the ISM. The sports industry is an important part of the health industry, and it is also an inevitable trend to integrate and develop with related industries and to innovate in business formats. The policies and documents related to the ISM are shown in Table 1.

Since the government issued the "Healthy China 2030" policy in 2016, the awareness of exercise to promote health has gradually spread among the public. However, there is no unified application mode of physical medicine in different provinces and cities. Many intervention studies focused on exercise improving disease symptoms, such as aerobic exercise improving blood sugar and insulin resistance in type 2 diabetes (11). The benefits of traditional Chinese sports on diseases are gradually being discovered (12). Under the background of the ISM, universities, especially those with sports related majors, focus on combining theory with practice to cultivate social sports instructors with comprehensive skills (13, 14). However, sports instructors lack professional certification, which is detrimental to their career development. Very few hospitals offer "exercise prescription" services because doctors are not experts in exercise. Doctors need the sports instructors' assistance, who are unable to work

in hospitals. This is the key to the ISM is difficult to achieve. The ISM services led by local governments is mainly aimed at raising residents' health awareness and encouraging them to participate in fitness activities (15, 16). At present, the development mode of the ISM in China is shown in Table 2.

The ISM is an important means to alleviate the contradiction between national health demand and medical supply. According to 2013 survey data: "Compared with 2008, the prevalence of chronic diseases in China has increased by 9%," which is equivalent to an increase of 120 million patients (17, 18). The rapid increase in the number of patients with chronic diseases has taken up a lot of medical and health resources. Medical and health institutions cannot effectively divert people's growing medical needs, which deepens the contradiction between supply and demand. This proactive, low-cost, and long-benefit "sports + medical" model promotes health to most people, thereby reducing the medical supply of patients and doctors. The ISM can divert some of the treatment places of chronic patients from hospitals to fitness places, to achieve the goal of optimizing medical resources, alleviating conflicts between doctors and patients, and reducing financial burdens.

Policy options and implications

Suzhou Model: A new attempt of the "Sunshine Fitness Card" policy

In 2005, the Suzhou Municipal Government formulated the "Sunshine Fitness Card" policy and issued the Notice on Doing a Good Job in Applying for the "Sunshine Fitness Card" for Medical Insurers. This is the first nationwide use of a combination of sports and medical care. Applicants can transfer the balance of their medical insurance account to the "Sunshine Fitness Card" as required for sports consumption in designated sports and fitness centers. In terms of transfer standards, the Suzhou Social Security Office has issued several standards for the transfer of amounts for applicants to choose from. According to the balance of the medical insurance account and combined with their exercise habits, the claimant can choose four types of personal account funds of 500 RMB, 1,000 RMB, 1,500 RMB, and 2,000 RMB to transfer to the special account of the "Sunshine Fitness Card" at one time.

So far, Suzhou has introduced the "Sunshine Fitness Card," and the number of people applying for the card and the transfer amount has been increasing year by year. In 2006, the number of people who applied for the "Sunshine Fitness Card" and the transfer amount were 1,116 and 67,500 RMB respectively; In September 2013, the cumulative number of people applying for a card in the urban area was 35,372, and the amount of 38,434,200 RMB in the medical insurance account was transferred to the citizen's fitness card. The designated cooperative sports venues expanded from the original 27 to 47. In 2014 alone, there

TABLE 1 Policies or documents related to the ISM.

File name	Main contents
Several Opinions of the State Council on Promoting the Development of the Health Service Industry. Beijing: General Office of the State Council (2013) (24)	"Guide relevant universities to reasonably determine the scale of training relevant professional talents… standardize and accelerate the training… rehabilitation therapists, health managers, fitness coaches, social sports instructors and other practitioners"
Several Opinions of the State Council on Accelerating the Development of the Sports Industry and Promoting Sports Consumption. Beijing: General Office of the State Council (2014) (10)	"Promoting the integration of the sports industry and other industries," and "actively expanding business formats, promoting the integration of sports and medicine, and encouraging mutual accommodation"
Outline of the "Healthy China 2030" Plan. Beijing: General Office of the State Council (2016) (6)	"Grasp the law of health development, adhere to prevention first"
The 13th Five-Year Plan for sports development. Beijing: General Administration of Sport (2016) (8)	"The sports industry inclines to the health of the whole people"
National Human Rights Action Plan of China (2016-2020). Beijing: General Office of the State Council (2016) (9)	"National fitness is an important way to achieve national health and a basic guarantee for all people to build up their health and lead a happy life"
China's Medium- and Long-term Plan for Prevention and Treatment of Chronic Diseases (2017-2025). Beijing: General Office of the State Council (2017) (7)	"The ISM will be the inevitable trend of serving public health and preventing chronic diseases in the future"
Opinions of the State Council on implementing the Healthy China Action Plan. Beijing: General Office of the State Council (2019) (15)	"People's health is an important symbol of the prosperity of a nation, and prevention is the most economical and effective health strategy"
Opinions of the State Council on Promoting the inheritance and innovation of traditional Chinese medicine. Beijing: General Office of the State Council (2019) (12)	"Promote the integration of traditional Chinese medicine, traditional Chinese sports and modern rehabilitation technology, and develop rehabilitation medicine with Chinese characteristics"
Outline of the "Healthy China 2030" Plan. Beijing: General Office of the State Council (2021) (16)	By 2025, the national fitness public service system will be improved, and people will enjoy more convenient sports and fitness, with 38.5 percent of people regularly taking part in physical exercise

were 6,163 people in Suzhou applying for Sunshine Cards. According to statistics, the average weekly consumption of card users reaches approximately 17,000 (19). In 2017, the Department of Human Resources and Social Security of Jiangsu Province has stopped the medical insurance transfer business and ended the form of economic binding between medical insurance and gymnasiums. Residents of Suzhou City can apply for Sunshine Fitness Card separately according to their needs, because Sunshine Fitness Card is very popular locally. This has played a positive role in guiding the public to exercise and fitness, improving the overall health of the whole people, and alleviating the pressure on local medical treatment. It is a beneficial attempt to ISM.

In 2016, with "Sunshine Fitness Card" as the carrier, the local government effectively integrated the sports and fitness venues with different business models, and built the "Sunshine Fitness Card" network service system throughout the city. The national fitness service covers the whole urban area of Suzhou, which basically meets the needs of citizens for nearby and convenient participation in fitness. As of June 30, 2020, Sunshine Fitness Card has a total of 79 designated venues, including swimming, fitness, badminton, basketball, football, physical test and other events.

The Suzhou Model is feasible for local sports departments and medical institutions to cooperate in the form of an all-in-one card. However, since the implementation of the "Sunshine Fitness Card" policy, there have been the following shortcomings:

(1) The depth of ISM is not enough: the practice of guiding participants to perform scientific exercises is relatively weak, and there is a lack of regular physical examination feedback and adjustment exercise plans for cardholders.

(2) Fitness facilities lack professional medical services: Fitness facilities do not provide physical fitness tests and effective guidance based on the health status of cardholders, thus turning fitness venues into "sports rehabilitation rooms" of medical departments, realizing proper integration of "sports" and "medical care."

Shanghai Model: "1+1+1" community active health project in Jiading District

In response to the strategy of building a healthy China, the Shanghai Municipal Bureau of Sports hosted the first Community (Shanghai) Sports Forum in 2016, the theme of which was "Changes in the Development and Construction of the Community Sports Organizations" (20). The forum put forward specific requirements in terms of physical fitness and medical services and introduced a "Community Active Health Plan." Jiading District, located in the northwest of Shanghai, took the lead in proposing the community ISM work model

TABLE 2 The development mode of the ISM in China.

Model	Illustration	Details
Community mode	Culture and Sports Service Center, Malu Town, Jiading District, Shanghai; National Physique Monitoring Station, Lucheng District, Wenzhou City, Zhejiang Province	Guided by the government and based on the community, it conducts residents' physical fitness monitoring, sports risk prevention, fitness guidance and health management.
Fitness club mode	Suzhou Sunshine Fitness Card program; UT Sports Clinic in Hefei	Medical rehabilitation institutions shall be established in sports venues. Make full use of the knowledge of medicine, sports and rehabilitation to evaluate the physical fitness of all members and put forward the corresponding exercise prescription.
Hospital mode	Beijing Beitaipingzhuang Hospital; Beijing Medical Examination Center	Special institutions have been set up in hospitals to carry out physical monitoring, disease prevention, and other work for chronic patients.
The combination of industry, university and research	Shenzhen Taishan Sports Technology Co., LTD.; Institute of Population, Peking University	Scientific research institutions cooperate with hospitals to carry out experimental attempts of physical and medical integration.
Multi-agent co-construction mode	Qingdao Institute of Integrative Medicine (ISM)	With first-class hospitals, research institutes and associations as multiple subjects and market-oriented, the construction of an innovation system will be promoted for the big health industry that integrates physical and medical services.

of which its main purpose is to: promote the ISM community physical test station and to promote non-medical health interventions. Furthermore, to take community comprehensive prevention and treatment methods for chronic disease patients, to receive scientific medical and health guidance, and relieve the condition through sports.

One of the measures is to incorporate health promotion into community medical services and build a "1+1+1" community work team, namely: one resident self-management team leader (recommended by patients), one community doctor and one social sports instructor. Among them, community family doctors provide medical consultation for patients; social sports instructors are responsible for teaching various fitness exercises and providing exercise rehabilitation guidance to patients with chronic diseases such as diabetes, and hypertension. Establish physical fitness monitoring centers in community streets to provide monitoring services. According to the inspection results, instruct community residents to carry out targeted exercises to improve the overall health level within the range of the community. In 2016, the district government issued the implementation plan of residents' fitness in Jiading District (2016-2020) (21). This has enabled the "1+1+1" community active health project to move toward an institutionalized and standardized operation track and promote the goal of building a healthy China. At present, the overall level of Jiading's national fitness is at the fore-front of Shanghai (22).

However, the "1+1+1" Community Active Health Project in Shanghai has also exposed the lack of enthusiasm interaction between sports and the medical system, and management obstacles in implementing the specific services of ISM. In the actual operation process, it relies too much on the government's health protection service function and often needs to rely

on neighborhood committees or streets to coordinate the work between sports and health departments, such as physical fitness monitoring, health promotion, business division, capital investment, and benefit distribution.

At present, some areas in China have made active attempts to provide health services based on the ISM. From the perspective of horizontal comparative analysis, the unique development mode of the ISM appears in various regions, which needs to be expressed and realized by explicit forms. For example, Suzhou "sunshine fitness card" policy and Shanghai "1+1+1" community active health project, which reflects the regional nature of the ISM and the specific development mode of the ISM should flexibly adapt to the regional economy, culture, and community sports development status. The ISM mode has not formed a fixed content and form, and there is no general health service mode. Thus, sports and health departments can actively cooperate with each other in health service projects, which is an important link to promote the realization of the ISM.

Actionable recommendation

In developing the ISM policy, we recommend the following based on available and relevant evidence.

Health service talent team building

The ISM service system involves knowledge in sports, medicine, nutrition, and health management. To ensure

high-quality service, it is necessary to establish a "sports-medicine" talent structure and recruit professionals to form a knowledge management team (23). At the policy level, the Several Opinions of the State Council on Promoting the Development of the Health Service Industry pointed out that "guide relevant universities to reasonably determine the scale of training relevant professional talents... standardize and accelerate the training rehabilitation therapists, health managers, fitness coaches, social sports instructors and other practitioners" (24). The "Healthy China 2030" Plan Outline mentioned: "Cultivate health education teachers and incorporate health education into the content of pre-service and post-service training for physical education teachers" (6). Under the guidance of the policy, colleges and universities, especially sports and medical colleges, can jointly set up professional courses and practical teaching system featuring ISM to cultivate comprehensive talents. The government should give special funds and facility support to the pilot universities to promote the training of ISM professionals. In addition, the government should establish a continuing education and vocational certification system of ISM to improve practitioners' professional recognition.

Strengthen the promotion and increase the publicity of ISM

Although Chinese residents have improved their awareness of health promotion and rehabilitation, they have not yet fundamentally understood the connotation of ISM. At the initial stage of the ISM trial, the service targets were mainly urban residents. The community is the main place for the spread of health concepts and the provision of ISM services. Thus, the promotion of the health concept of ISM in urban communities should be strengthened. For example: to strengthen the health risk awareness of adolescents, cultivate their good lifestyles and lifelong exercise habits; conduct publicity and education on disease prevention and scientific exercises to residents in community service centers, and provide health consultations to promote residents to establish a correct outlook on exercise and health; make full use of the media, newspapers, and the Internet to promote the health value of ISM to the society.

Practice ISM based on regional characteristics

The development of ISM in China is in its infancy and has not yet formed a fixed content and form. Sports and medical management departments should actively cooperate,

formulate guiding opinions and policies, and do reasonable coordination work in terms of business division and benefit distribution. The health service projects in which the sports and medical departments can cooperate in the region should be selected according to the actual situation to meet the health service demands of residents in various regions. For example, the State General Administration of Sports and Beijing TV Sports Club jointly planned a pilot program called "Moving for Pregnancy" (25). This program is recommended by experts from Beijing Tiantan Hospital to 100 obese patients with polycystic ovary infertility to receive a 28-day exercise weight loss course at the Fitness Center of the Training Bureau of the State Sports General Administration. Each class is 1.5 h and 2 to 3 classes per week. Changzhou Sports Hospital (Jiangsu, China) screens people with sub-health and chronic diseases through physical examinations and sets up a special health consultation room in the Sports and Health Promotion Center to facilitate patients to understand the specific content of the ISM (26). Although the exact form of practice has not been formed, the exploration of promoting the ISM in some provinces and cities undoubtedly provides a useful reference for the ISM into a scientific and reasonable development track.

Conclusion

The ISM policy meets people's needs for sports, medical treatment and health at the community and family levels, and has become a new health service model for the public. ISM embodies the mutual complement and promotion of sports and medicine. The implementation of sports training for health promotion is an appropriate choice in response to the ISM policy. The "Suzhou Model" and the "Shanghai Model" are valuable attempts to implement the policy of ISM, laying the foundation for the combination of "Sports" and "Medicine" in the future. At present, the coordinated development of ISM in China is still in its infancy, and there are still some shortcomings in the implementation of the ISM model. Research on the model still requires the cooperation of the government, society, schools, and others including private sectors to promote the long-term operation of the development model, to realize the function and effect of ISM under the new situation.

Author contributions

SG and LD conceived the manuscript and revised drafts. TZ and ZN wrote the first draft. 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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Establishment of the emergency material reserve mechanism for public health emergencies and optimization of the management of various functional departments

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Public health emergencies refer to emergencies caused by various factors that may cause serious harm to society. This paper mainly discusses how to establish an emergency reserve mechanism for public health emergencies. This paper proposes a comprehensive evaluation system for emergency response capabilities based on analytical methods, and analyzes the emergency response to public health emergencies and various functional management departments. The experimental results show that the implementation rate of disease prevention and control projects in the city center is 59.3%, and the average completion rate of inspection projects by district and county health supervision agencies is 45.8%. However, these achievements are far from enough. Therefore, the training of relevant personnel should be strengthened and run through the material reserve work from beginning to end. At the same time, an emergency material reserve system should be established. According to actual needs, timely provide emergency disposal materials to ensure normal supply. In response to the current public health emergencies, multiple departments and units should further strengthen management personnel allocation and optimize work processes to promote the development of public health.

KEYWORDS

public health events, emergency response, material reserve, optimization assembly, material reserve mechanism

1. Introduction

Public health emergencies refer to the hazards to public health caused by the outbreak of major infectious diseases, mass diseases of unknown causes, major food, occupational poisoning and other situations that endanger public health. Broadly speaking, it refers to the outbreak of major infectious diseases, infectious diseases of unknown causes, new infectious diseases, mass reactions of vaccines, mass drug reactions, major food poisoning, major environmental pollution, acute occupational poisoning, radiation pollution, radiation accidents, biological, chemical, nuclear radiation, major animal

infectious diseases, natural disasters, accidents, public security and other emergencies. It has the characteristics of sudden, unexpected, mass, public, high-frequency, diversified, international, comprehensive, systematic, etc. It has the characteristics of multi disaster, disastrous and destructive. The sudden public health events not only endanger the public's physical and life safety, but also may cause psychological panic, even cause social chaos, economic recession, and threaten national security. The emergency response mechanism for public health emergencies of the CDC cannot be completed overnight, but is a long process. In the process of establishing the emergency system, it is necessary to conduct timely research and evaluation to understand the current situation and existing problems, and formulate corresponding countermeasures according to these problems to ensure the effectiveness of the system construction and operation, so as to effectively improve the work efficiency. This article discusses how to build the reserve mechanism of emergency disposal materials and the best management mode of each functional department in public health emergencies, with a view to making certain contributions to public health emergencies.

According to the existing research progress, different researchers have also conducted corresponding cooperative research on public health events. Li et al. (1) conducted an in-depth study on the spatio-temporal distribution characteristics and related influencing factors of Internet users' perception of public health event risk. Pan et al. (2) analyzed the main events and intervention methods of the COVID-19, and assessed the correlation between public health intervention measures and the epidemiological characteristics of COVID-19 epidemic in Wuhan in five periods. The concept of acute public health events usually assumed that they were resolved entirely or mainly through technical and medical solutions. In order to better understand this connection, Whittaker et al. (3) used the perspective of disaster diplomacy to analyze and evaluate the impact of acute public health events on diplomatic outcomes. McCullough et al. (4) estimated the direct cost of carrying out emergency preparedness and response activities simultaneously to deal with three major public health events. However, these scholars did not analyze the emergency response to public health events. In this regard, relevant documents on emergency handling events were consulted.

Some scholars also have some research on emergency response. Rose et al. (5) highlighted the development of public health emergency management in recent years, and discussed many cross issues in public health and emergency management. Public health events have caused great harm. Emergency management requires the strength of government departments, pharmaceutical enterprises, citizens, new media and other forces. Therefore, what are the effects of different choices of citizens and news media in responding to emergencies? In response to the above problems, Lu et al. established a four-dimensional evolutionary game model, which divided two types of citizen participation models into two categories: real assessment and false assessment. There are two ways for new media to participate: one is confirmed reports, the other is unconfirmed reports (6). However, these scholars did not discuss the establishment of the emergency response material reserve mechanism for public health emergencies and the optimization of the management of various functional departments, but only unilaterally discussed its significance.

This paper drew the following conclusions by studying and analyzing the optimization experiment results of public health emergency response and management of various functional departments. In order to deal with public health emergencies, effective measures should be taken to strengthen the management of relevant personnel. The regular material preparation system was established. According to actual needs, sufficient emergency disposal materials were arranged to ensure their normal supply.

The innovations of this paper are as follows: (1) The emergency handling material reserve process is explained, and the comprehensive evaluation method of emergency response capability based on the analytic hierarchy process is proposed. (2) The emergency response of public health events and the optimization of the management of various functional departments are experimentally analyzed.

2. Establishment of emergency response methods for public health emergencies

2.1. Emergency disposal material reserve process

The reserve of emergency handling materials for public emergencies refers to the reserve requirements for various emergency handling materials and equipment required to prevent and control public emergencies or disasters, including tents, folding beds, disinfection cabinets, sanitary toilets, emergency vehicles and other emergency handling materials. The preparation and implementation of the reserve plan for emergency materials shall include the types, quantities and storage methods of materials required. The types of emergency materials include: general protective articles, equipment and equipment, emergency equipment and materials, medical equipment, other living articles and other urgently needed items.

First of all, governments at all levels should establish an effective emergency materials reserve mechanism to effectively implement the emergency materials management system and achieve full coverage of emergency materials reserve for public health emergencies. At the same time, it has formed a complete and efficient management system (7, 8). Figure 1 shows the full coverage of emergency materials reserve. Secondly, governments at all levels should implement a centralized

FIGURE 1
Full coverage of emergency materials reserve.
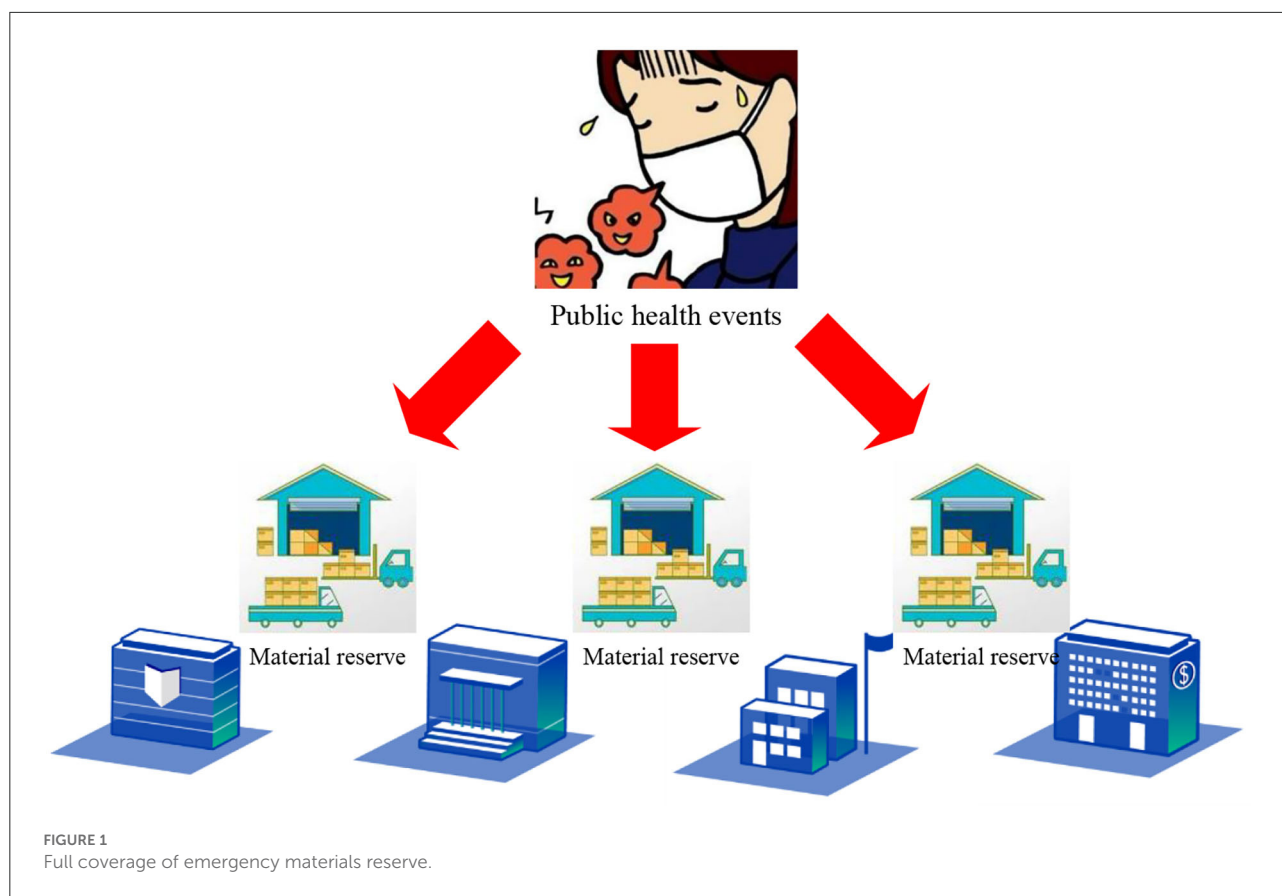
supply system of unified planning and allocation for emergency materials to form a unified centralized procurement system for emergency materials and implement a whole process tracking and supervision system. In addition, governments at all levels should also evaluate and supervise the reserve of emergency materials to form an evaluation and supervision management system and implement a whole process tracking and supervision system. The public purchase mechanism of emergency materials has been established to ensure that the market mechanism plays an effective role. The training mechanism for emergency materials management personnel has been established to ensure that they can allocate and use emergency materials in accordance with the law. The emergency materials management information system has been set up and its operation status has been disclosed to the public in a timely manner to facilitate the public's inquiry, supervision and management of the emergency materials reserve (9, 10). Finally, it is necessary to establish a communication and coordination mechanism among various government departments to timely communicate and solve the problems and difficulties in the work of emergency handling material reserves. Adequate supply of various materials is the precondition to ensure efficient and orderly disposal of public health emergencies. Emergency disposal material reserve is one of the important links to maintain social stability (11, 12). It is not only the material reserve itself that plays a decisive role in the disposal of public health emergencies, but also whether

each department in the coordination mechanism of emergency material reserve can achieve information communication, personnel integration, material allocation, etc.

2.2. Strengthen organization and leadership to form resultant force

A sound emergency disposal material reserve system has been established. Relevant systems have been developed according to relevant requirements, and organizational leadership has been strengthened. A leading group consisting of the Municipal Health Commission, the Municipal Bureau of Commerce, the Municipal Big Data Bureau and other member units is established, and a regular meeting system is established to study and solve the problems in the emergency response reserve work. The organization and leadership system has been established and improved, and the public health emergencies, response processes and standards have been clarified. The responsibility is implemented, and the linkage mechanism of various departments is established to form the leadership system and working mechanism for responding to public health emergencies. The supervision and inspection of the medical protection material reserve is carried out regularly. The inspection results are included in the scope of

responsibility assessment for the year-end objectives of the unit, forming a supervision and restraint mechanism, which can promote the relevant departments to effectively carry out the management of medical protection material reserves within their responsibilities. Work meetings are held regularly to study and deploy relevant work.

2.3. Comprehensive evaluation of emergency response capability based on analytic hierarchy process

The evaluation of emergency response capability is the basic evaluation of the emergency management system. It is a comprehensive evaluation of the possible disaster accidents, natural disasters and other natural disasters when emergencies occur. It also is a strategic decision that the country should make in response to emergencies in emergency management.

Calculation of index weight: Analytic Hierarchy Process (AHP) is adopted, and the influence degree of each index is divided into multiple levels to determine its interdependence. Considering the operability of the actual evaluation, a hierarchical index system is established. On this basis, the evaluation matrix is established by evaluating the relationship between the indicators, and the weight of each indicator is calculated according to the following formulas.

$$E_o^{'} = \sqrt[z]{s_{o1}s_{o2} \cdots s_{oz}} \tag{1}$$

$$E_o = \frac{E_o^{'}}{\sum_{o=1}^{z} E_o^{'}} \tag{2}$$

In the above formulas, $E_o^{'}$ is the initial weight coefficient and E_o is the normalized weight of the indicator.

Consistency test and overall consistency test are conducted for the acceptability of index weight coefficients. The consistency ratio (CR) is less than 0.1, and the consistency is relatively satisfactory.

The consistency index (CI) is calculated as follows:

$$CI = \frac{\bar{\gamma} - z}{z - 1} \tag{3}$$

$$\bar{\gamma} = \frac{\sum_{o=1}^{z} \gamma_o}{z} \tag{4}$$

$$\gamma_o = \frac{\sum_{k=1}^{z} s_{ok}E_k}{E_o} \tag{5}$$

In the above formulas, z is the number of sub targets of the inspected level. $\bar{\gamma}$ is the average of z characteristic roots. γ_o is the o-th characteristic root of the comparative judgment dominance matrix of the sub targets at this level. s_{ok} is the corresponding eigenvector.

The random consistency ratio CR is calculated as follows:

$$CR = \frac{CI}{RI} \tag{6}$$

RI is a random index of the decision matrix.

In order to prevent the accumulation of minor inconsistencies from causing serious inconsistencies, it is also necessary to combine the consistency check with the overall consistency check. Let the consistency ratio of the first level judgment matrix be $CR_{(1)}$ and the weight vector of the first level index be $(n_1, n_2, \cdots n_m)$. The consistency indexes of the second judgment matrix are $CI_1, CI_2, \cdot CI_m$. The order of the second judgment matrix is $y_1, y_2, \cdot y_m$. The consistency ratio of the portfolio is:

$$CR_{(2)} = \frac{\sum_{o=1}^{m} n_o CI_o}{\sum_{o=1}^{m} n_o RI_{(y_o)}} \tag{7}$$

In the above formula, $RI_{(y_o)}$ is the random consistency index of positive and negative matrices of order.

The formula for calculating the overall consistency ratio is:

$$CR^{*} = CR_{(1)} + CR_{(2)} \tag{8}$$

The evaluation score of emergency response capability for public health emergencies is a comprehensive evaluation of the emergency response capability of medical institutions, and its comprehensive evaluation score reflects the response capability of medical institutions during this period (13, 14). Figure 2 shows the application of AHP in public health emergencies. When establishing the evaluation system of emergency response capability by establishing a calculation model to determine the participation of each subject, the hierarchical structure and hierarchical weight are analyzed and compared. The adoption of hierarchical structure and hierarchical weight calculation method makes each object have good consistency, which reflects the internal relevance and variability of each subject in the field of emergency management, thus making the evaluation results more comprehensive and objective.

On this basis, the weighted linear method is used to calculate the product of the weight of each index and the measurement results, and the comprehensive evaluation index is obtained. The formula is as follows:

$$W = \sum_{o=1}^{m} Q_o \bullet R_o \tag{9}$$

In the formula, W is the comprehensive evaluation index of the emergency response capacity of urban prevention and protection stations for public health emergencies. Q_o is to calculate the score of each index according to the dimensionless method. R_o is the comprehensive weight of the evaluation index. M is the number of evaluation indexes participating in the evaluation.

AHP method is used to establish the evaluation index system of emergency response capability. Through careful analysis of the indicators, and according to the actual situation, the subordination of each indicator is determined, and the correlation of each indicator element is noted to meet the

FIGURE 2
Application of analytic hierarchy process in public health emergencies.
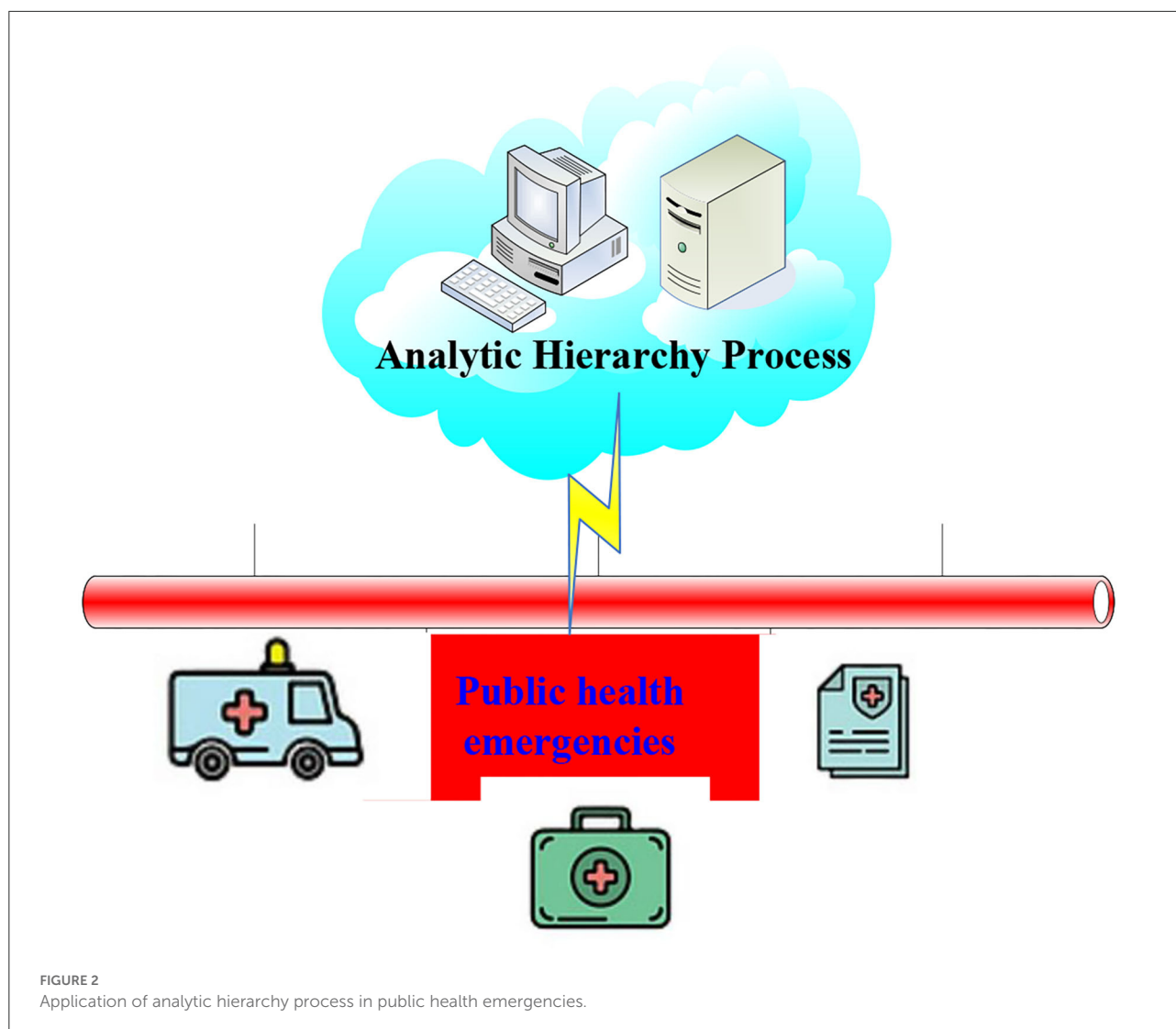
attribute requirements of the upper level indicators. AHP method is used to study the evaluation index of emergency response capability, which fully reflects the idea of combining qualitative and quantitative methods in system theory.

3. Experimental results of optimization of public health emergency response and management of various functional departments

3.1. Emergency management mechanism

The establishment of material reserve mechanism for handling public health emergencies is the first step to ensure epidemic prevention and control. On the one hand, it is necessary to ensure national unity and centralized and unified command of authority. In the face of public health emergencies, the state should adopt a unified allocation model. On the other hand, it is necessary to establish a set of systems to plan, coordinate and manage the governments at all levels from the national level. The government and market entities shall specify the responsible subjects for providing material support after public health emergencies. At the same time, it should be made clear that the state should organize and carry out corresponding emergency response work immediately after the public health emergency. The establishment and management process of emergency response material reserve mechanism can improve the efficiency and effectiveness of all departments in dealing with public health emergencies (15, 16). The second step is that the government should make corresponding planning, design and arrangement according to the requirements of emergency response work to formulate relevant policies and regulations. It is ensured that the tasks of governments at all
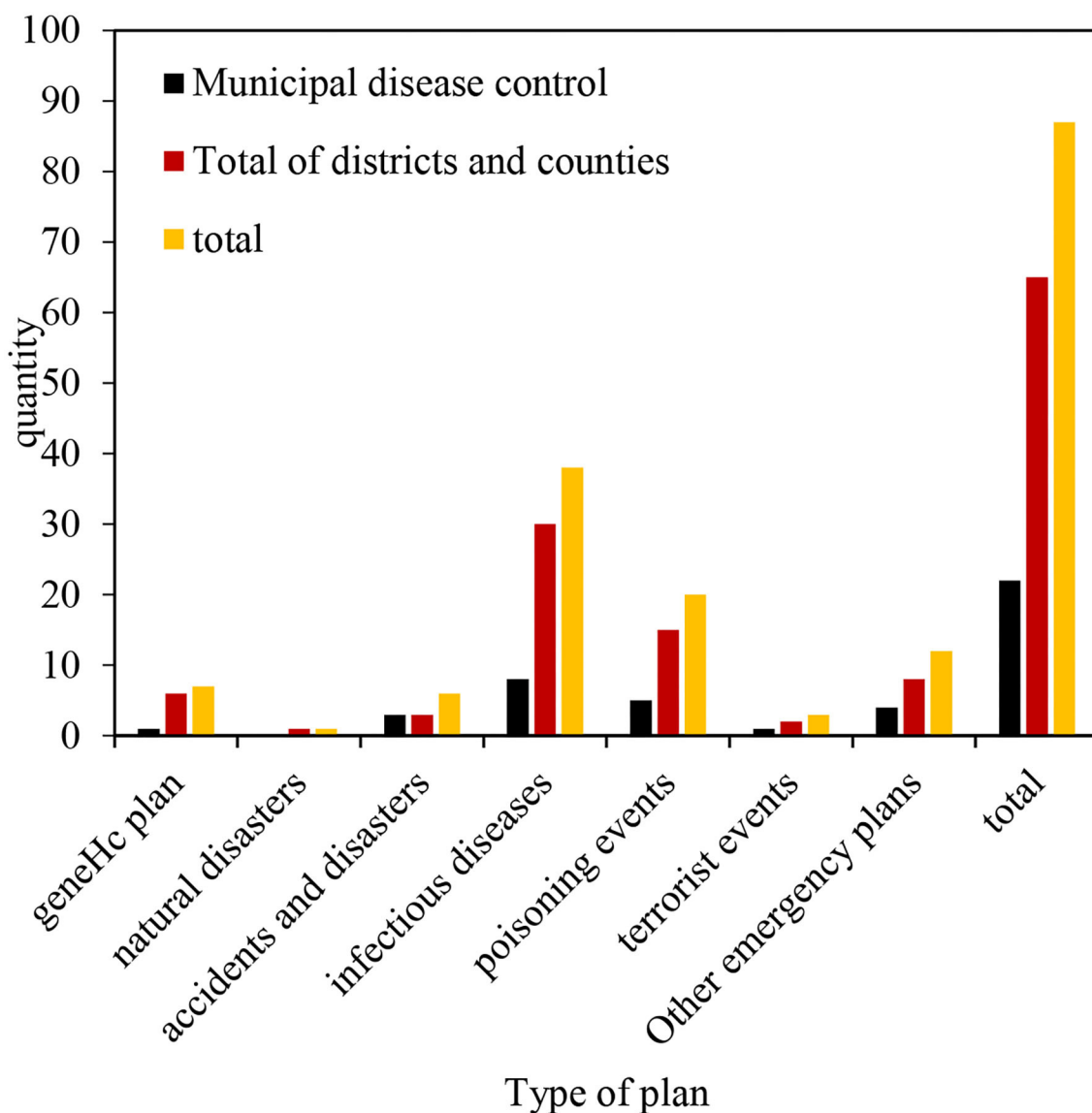
FIGURE 3
Plan formulation of disease prevention and control institutions in M City.

levels and departments are not absent or offside, which requires responsibility and accountability. The emergency response work should be effective and quality. The management should be open and transparent, free from blind spots and loopholes, and not affect the overall situation. This paper is illustrated by M City.

Disease prevention and control institutions in M City have corresponding emergency response and technical plans, including the overall plan and six special plans, totaling 87. Among the emergency plans formulated in the city, 38 are the emergency plans for public health emergencies caused by infectious diseases. Twenty are the emergency plans for poisoning events. Twelve are the emergency plans for other types of public health emergencies. There are seven overall plans, six

emergencies, three terrorist events, and one natural disaster. As shown in Figure 3, it is the emergency plan of M City Center for Disease Control (CDC).

3.2. Basic information of health emergency team

(1) Establishment of health emergency team

As of the end of 2018, there are 207 medical emergency teams in M City CDC. Among them, there are 16 emergency
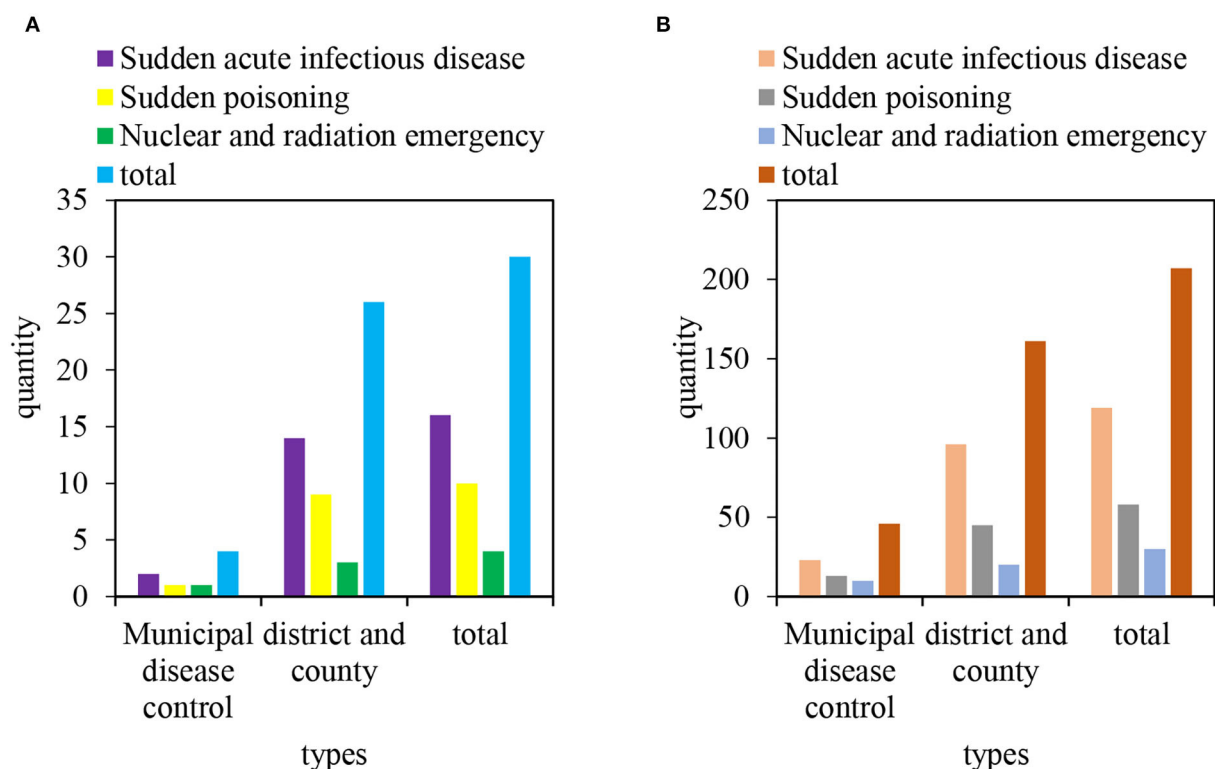
Establishment of health emergency response team of disease control institutions in M City. **(A)** Number of teams. **(B)** Number of personnel.

infectious disease prevention and control teams with 119 people. There are 10 disposal teams of 58 people for poisoning emergencies. There are 4 medical emergency teams with 30 people for nuclear radiation emergencies. Among them, there are 46 people from 4 departments of the municipal CDC and 161 people from district/county CDC. There are 14 emergency response teams for sudden acute infectious diseases, 9 emergency response teams for sudden poisoning, and 3 emergency response teams for nuclear and radiation. It can be seen that the construction of the emergency response team is dominated by sudden acute infectious diseases and sudden poisoning accidents, and there is a lack of attention to the emergency response work of nuclear and radiation accidents. As shown in Figure 4, Figure 4A is the number of teams and Figure 4B is the number of personnel.

(2) Age distribution

The health emergency workers of the CDC in M City are mainly concentrated in people aged 40~50, accounting for 52.17%. The population aged 30–40 years accounts for 30.44%. The proportion of people under 30 years old is 12.08%. 5.13% are over 50 years old. Among them, 14.91% are under 30 in district/county disease control units. The population aged 30–40

years accounts for 32.92%. The population aged 40–50 years accounts for 49.07%. The population aged over 50 accounts for 3.1%, as shown in Table 1.

3.3. Health emergency fund guarantee

The main source of emergency funds is local government funds. Emergency funds are mainly used for emergency disposal (investigation, disposal and inspection of emergencies), as well as storage of emergency materials (including antibacterial drugs, protective equipment, field equipment, communication equipment, etc.), and daily emergencies (training, drilling, and preparation of plans).

Among the eight centers for disease control and prevention, only the municipal centers for disease control and the four centers A, D, E, and H have included medical emergency funds and medical emergency reserve funds in their annual budgets every year. From 2016 to 2018, the daily funds of the CDC in the city are 1,00,000, 1,80,000, and 2,10,000 yuan, and the emergency reserves are 50,000, 80,000, and 1,10,000 yuan. The funds of district and county disease control departments are 3,00,000 yuan, 1.025 million yuan, 1.19 million yuan, and the emergency reserves are 1,70,000 yuan, 2,00,000 yuan, and 2,60,000 yuan,

TABLE 1 Age of health emergency personnel in disease control institutions in M City.

		Municipal disease control	District and county disease control	Total
Under 30	Number of people	1	24	25
	Proportion	2.17%	14.91%	12.08%
30–40	Number of people	10	53	63
	Proportion	21.74%	32.92%	30.44%
40–50	Number of people	29	79	108
	Proportion	63.05%	49.07%	52.17%
Over 50	Number of people	6	5	11
	Proportion	13.04%	3.1%	5.31%

FIGURE 5
Emergency funds of disease control institutions in M City from 2008 to 2010. **(A)** Daily work fund, **(B)** Health emergency stockpile.
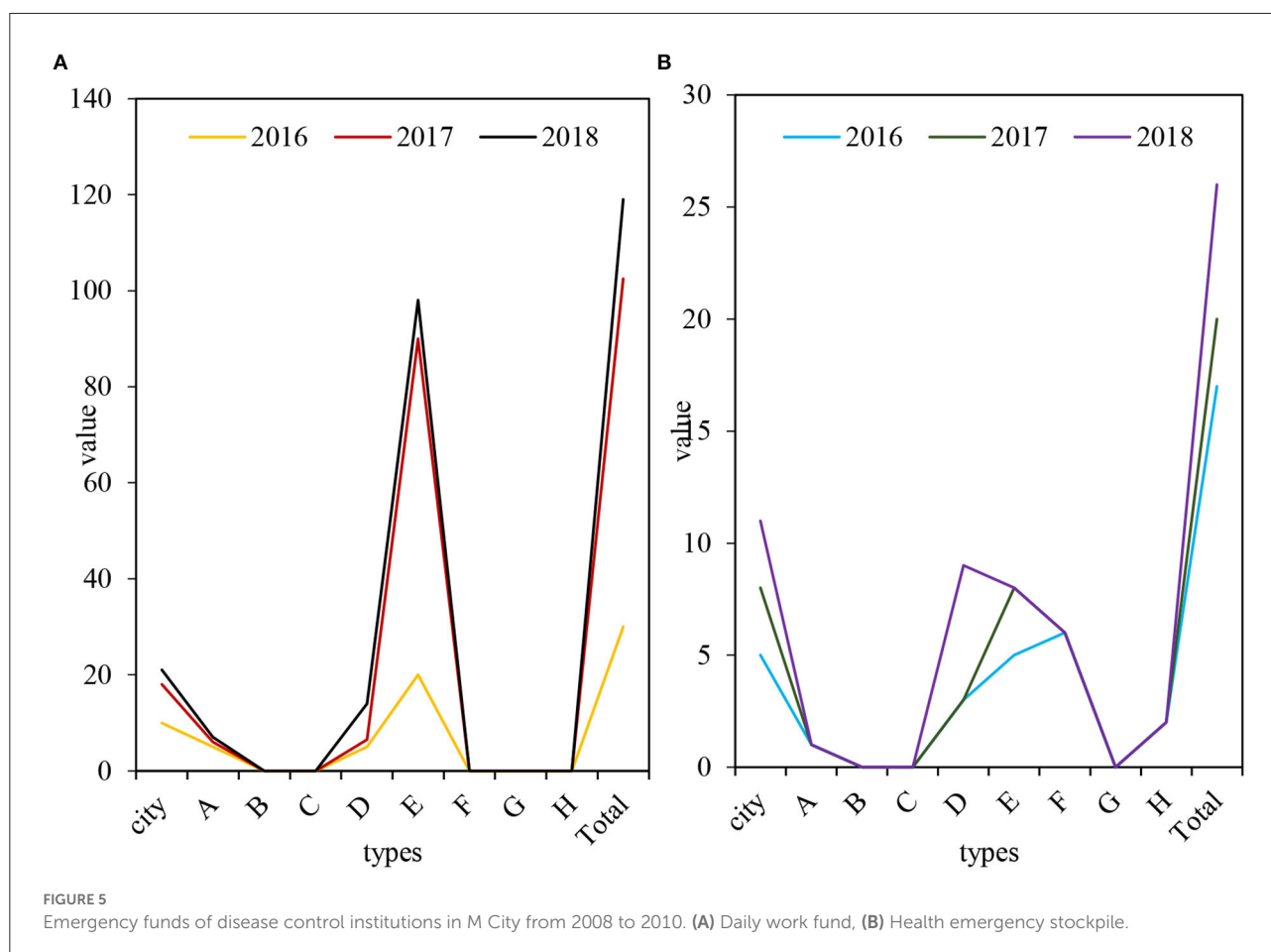
showing an increasing trend year by year. According to the survey results, the expenditure amount of each department is compared. Most of the Centers for Disease Control and Prevention have included the emergency fund in their financial budgets. They believe that the current emergency disposal costs simply cannot meet the needs of actual work. Only a few people feel that this is just a barely able to adapt to the requirements of work. As shown in Figure 5, Figure 5A is the daily work fund (10,000 yuan), and Figure 5B is the health emergency reserve (10,000 yuan).

3.4. Laboratory testing capability

It can be seen from Figure 6A shows the projects that should be carried out and actually carried out by the disease control institutions in M City. Figure 6B shows the project implementation rate of the disease control institutions in M City. There are 226 work projects that must be carried out by the municipal CDC, 134 of which are actually carried out, accounting for 59.3%. A total of 118 inspection items should be implemented by the district/county CDC, of which 54

FIGURE 6
Work items that must be carried out by disease control institutions in M City. **(A)** Projects that should be carried out and actually carried out by the CDC in M City. **(B)** Project implementation rate of disease control agencies in M City.
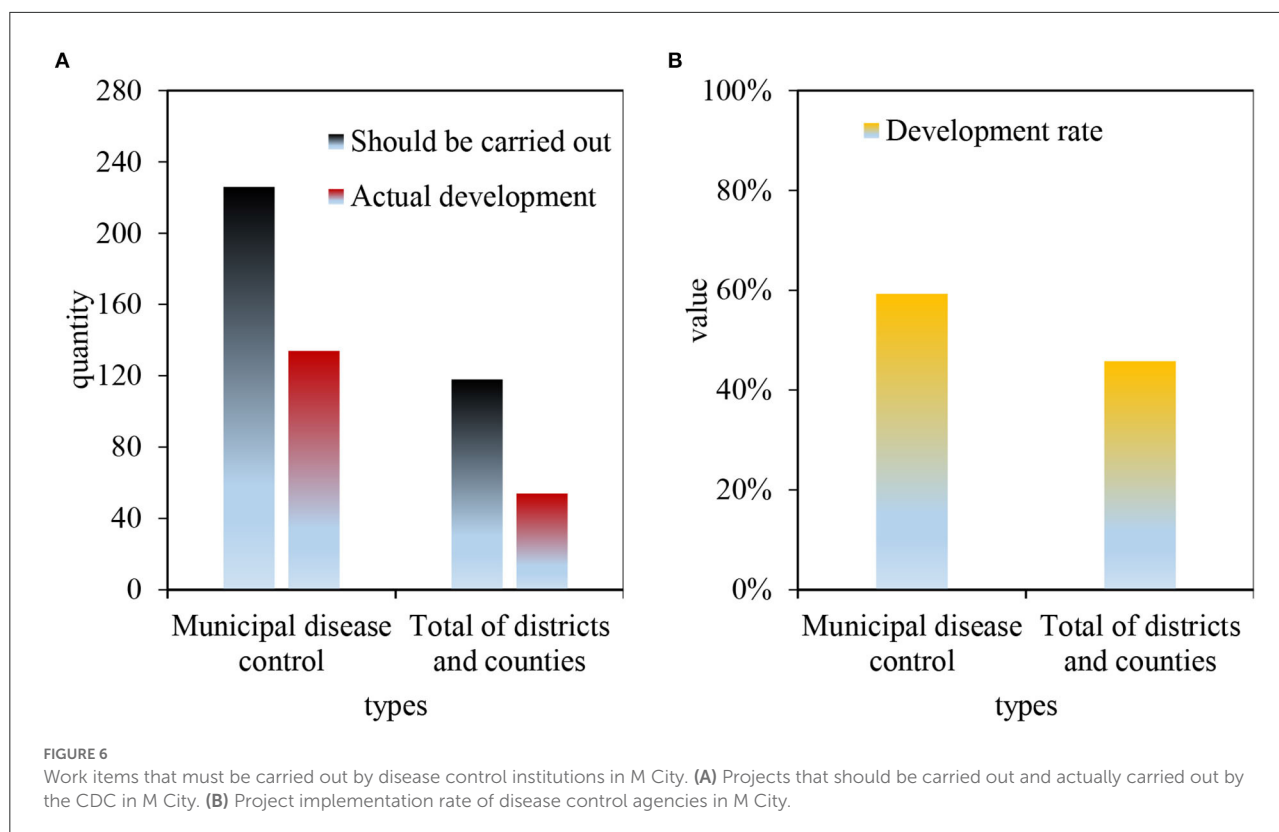
items are actually implemented, with an average completion rate of 45.8%.

It can be seen from Figure 7A shows the projects that should be carried out and actually carried out by the disease control institutions in M City. Figure 7B shows the project implementation rate of the disease control institutions in M City. According to the regional characteristics and the work items to be carried out, 133 municipal disease control institutions should be completed. Among them, 27 projects are actually completed, accounting for 20.3%. District and county health management institutions should carry out 61 projects, and actually carry out 9 projects, with an average implementation rate of 14.8%.

3.5. M City's demand for emergency system construction of disease control institutions

It can be seen from Table 2 that the construction of the emergency system of the CDC in M City focuses on the construction of organizational structures (9), the increase of staff (9), the construction of troops and equipment (8), medical and emergency medical funds (9), emergency medical supplies reserves (7), the establishment of emergency measures (4), the treatment of emergency members (4), and the establishment of the emergency planning system (3).

4. Discussion

Effective measures should also be taken to strengthen the management of relevant personnel in response to public health emergencies. First of all, a high-quality management team should be established. At present, many government departments and enterprises have different levels in the reserve management of emergency materials. In the process of formulating the reserve plan for emergency materials, it has not been implemented in strict accordance with the requirements of the provisions on the management of emergency materials. There are unscientific phenomena in the preparation of the reserve material plan. The emergency materials reserve plan blindly reserves materials without actual operation and use. Secondly, in the process of material storage, if the materials needed for some emergencies are not in place in time for handling, the emergency handling material storage plan cannot complete the actual consumption and disposal as required, affecting the normal production order. Therefore, the training of relevant personnel should be strengthened and run through the whole material reserve work.

FIGURE 7
Work items to be carried out by disease control institutions in M City according to regional characteristics and needs. **(A)** The work items that the disease control agency of M City needs to carry out according to the regional characteristics. **(B)** The implementation rate of the work items that the disease control agency of M City needs to carry out according to the regional characteristics.

TABLE 2 Recommended demand for health emergency system construction of disease control institutions in M City.

Proposal	Number of institutions
Strengthen the construction of health emergency organization and establish a full-time emergency office	9
Increase staffing and set up full-time health emergency management personnel	9
Unify equipment allocation standards and strengthen team and equipment construction	8
Set up special emergency funds for special purpose	9
Establish emergency reserve mechanism	7
Coordinate the government to establish operational emergency rules and regulations	4
Improve the treatment of health emergency team members and implement risk assurance	4
Improve plan construction	3

A normalized material reserve mechanism is established to provide sufficient emergency materials according to the actual situation and ensure their normal supply. At the same time, corresponding work processes should be developed to sort out and optimize each link to ensure the orderly and effective operation of the whole process, so as to avoid excessive dispersion and waste. All departments should coordinate and cooperate with each other, and strengthen publicity and education, which gives full play to the role of public participation. The establishment of a scientific and effective mechanism to deal with public health emergencies is one of the important guarantees for doing all work well. For the problems and weak links exposed in the daily work of many departments and units in public health emergencies, it is also necessary to strengthen the allocation of managers and the optimization of work processes in these departments, so as to better promote the development of public health.

5. Conclusions

A long-term mechanism for emergency materials management should be established. At ordinary times,

relevant materials shall be stored according to the needs and relevant standards. The implementation of material reserve has been checked regularly to find problems and report them in time. It is also necessary to do a good job in the delivery and management of emergency materials. Emergency materials shall be allocated and used by all functional departments. In the process of responding to public health emergencies, it is not only necessary to ensure the adequate supply of materials, but also to timely and accurately convey information to everyone, which ensures the timely distribution of materials in place to maximize their role. This must be fully considered, accurately designed and reasonably allocated to ensure the efficiency, safety and fair use of resources. After the establishment of emergency disposal donation warehouse, the management method for emergency disposal donation materials should be established and improved as soon as possible to clarify the division of responsibilities and operating procedures of all parties, and ensure the quality, safety and effectiveness of emergency disposal materials. At the same time, system documents such as operating procedures for the use of donated materials for emergency disposal and acceptance management measures should be developed and improved. The use process and relevant regulations of donated funds and materials shall be clarified, and the use specifications, management requirements and principles of donated funds and materials shall be clarified. At the same time, the management of donated money and materials has been strengthened to effectively improve the use efficiency of donated money and materials. However, due to the limitations of time and technology, this article did not elaborate on the problems encountered in the emergency response to public health emergencies, which would be further analyzed later.

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

YS: writing—original draft preparation, editing data curation, and supervision.

Conflict of interest

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

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Evaluation on the psychological adjustment and countermeasures of civil servants in public emergencies

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Public health emergencies are inevitable major development crises, and there are almost no omens of any emergency. The current social development would inevitably affect the psychological situation of civil servants. Grass roots civil servants have a wider range of tasks, more difficult working conditions and a more difficult environment. Under the strong social pressure, civil servants would also have negative factors such as fear and negative attitude. The mental health of grass-roots civil servants depends not only on the image and efficiency of the government, but also on creating a harmonious atmosphere and the quality of economic development. Therefore, people must pay attention to the psychological health of civil servants. It is mainly through psychological intervention and psychological adjustment to improve mental health. By analyzing the psychological characteristics of civil servants under emergencies and under pressure, and according to the importance of their coping ability under emergencies, this paper conducted corresponding psychological adjustment and psychological intervention to ensure the psychological health of civil servants, improve their ability to deal with public emergencies, and enable them to use correct and positive psychology to deal with public emergencies. It can be seen from the firefly algorithm that the prediction error value of the comprehensive quality of civil servants was declining, while the evaluation effect of the comprehensive quality was rising. The average value of the prediction error value of the comprehensive quality was about 0.49, and the average value of the evaluation effect of the comprehensive quality was about 0.73. In the whole process, the prediction error value of comprehensive quality decreased by 0.37, and the evaluation effect of comprehensive quality increased by 0.33. The comprehensive psychological quality and psychological adjustment ability of civil servants after psychological intervention were better than those before psychological intervention. The comprehensive psychological quality of civil servants after psychological intervention was 8.56% higher than that before psychological intervention, and the psychological adjustment ability was 8.47% higher than that before psychological intervention.

KEYWORDS

civil servants' psychological adjustment, public emergencies, public health, psychological response measures, comprehensive psychological quality

1. Introduction

Public health emergencies show that governance is the most effective means to stabilize public order. When life is threatened, the ability of government officials to respond to emergencies and the impact of their ability to respond is a major challenge for government officials, because the handling effect of emergencies affects the public's attitude toward the government. In this regard, this paper analyzes the impact of civil servants' emergency response

capacity on health emergencies, reviews the psychological situation of civil servants in health emergencies, and puts forward appropriate plans to improve their psychological situation, which has important practical significance for the psychological adjustment of civil servants.

The psychology of civil servants is a research that cannot be ignored. Borst et al. (1) used the insights in the public management literature to expand the job search demand resource model of work participation, and public organizations can choose people with positive personality and high public service motivation by adding work related resources, improving the speed of emergency response by selecting high-level managers. Borst and Lako (2) combined the work demand resource model and high-performance work practice classification, and analyzed the determinants of pride, The professional pride of civil servants would hardly be affected by high performance work practices. Costantini (3) studied the extent to which the improvement of psychological capital as a personal resource can improve the work participation of public sector employees, aiming to investigate the intervention measures to improve the work participation by enhancing psychological capital. Qing (4) investigated the impact of moral leadership on employee attitudes (emotional commitment and job satisfaction), and studied the role of psychological empowerment as a potential mediator of these relationships. Borst (5) found out whether the impact of work participation on the attitude, behavior and performance results of the non-public sector and the public sector was as high as expected, and whether these relationships were different among the public, non-public and private sectors. Husain (6) explored the obstacles preventing Pakistanis from seeking psychological help, and suggested that mental health practitioners in the country improve their awareness of mental health and improve mental health services. Duran et al. (7) believed that psychological contract can provide rich insights for understanding the relationship between employees and employers within the police, as well as the pressure and wellbeing of the police, and used framework analysis to analyze these interviews. The above studies all described the psychological characteristics of civil servants, but did not describe psychological intervention measures.

Many scholars have studied the psychological intervention measures of civil servants. Wang believed that while controlling the epidemic, the government should also pay attention to the mental health of the general public, medical workers and patients with mental disorders. Other measures for patients with mental disorders may play a crucial role during the pandemic (8). Saito (9) estimated the changes in mental health, quality of life and unemployment experience of ordinary workers during the first COVID-19 outbreak in Japan. The purpose is to assess the psychological changes and impact of public servants in emergency. Zou (10) found that public trust in the government is conducive to alleviating their psychological crisis through regression analysis of public questionnaire data. Zhong (11) investigated the psychological status and countermeasures of hospital guidance nurses, and analyzed the interview data with color analysis method to provide strong psychological support for the triage work of nurses. The above studies all described the measures of psychological intervention, but there are still some deficiencies in psychological adjustment.

At present, there are few researches on the psychological health of civil servants, which are all individual studies, with no common analysis and problems such as standardization, decentralization and alienation. The neglect of civil servants' mental health not only has a negative impact on the development of civil servants themselves, but also has a negative impact on the improvement of the political system and the healthy development of society. Mental ill health would affect social governance and emergency handling. The mental health problem of civil servants has destroyed the ecological balance between the administrative system and the administrative structure, and reduced the attitude and efficiency of civil servants at the grass-roots level, which has seriously affected the efficiency of social services and public affairs management, and hindered the exercise of administrative power.

2. Evaluation of the psychological status of civil servants in public emergencies

2.1. Characteristics of public emergencies

There are three main characteristics of public emergencies, as shown in Figure 1. First, it is very unpredictable. An emergency is a temporary emergency that does not occur in the normal process of development, nor is it consistent with the normal trend of development. The operation of modern society often has certain regularity, and many social problems must be standardized, mainly by improving the psychological quality of government administrators. However, due to some subjective factors, the laws of social development and working rules would be broken, which makes unforeseen events different from the development trend and normal operating procedures. Because of the variety of factors that cause emergencies, it is difficult to predict in advance, which is the unpredictability of emergencies. Second, it is harmful to society. In general, emergencies often have a negative impact on social and economic development and the personal and financial security of citizens. For example, it is difficult to prevent and predict public security events that are centrally handled in social emergencies in advance, and most of the fund time would involve personal and property safety, which is extremely harmful to society (12). The third is the universality of social consequences. With the rapid development of society, the relationship between all social strata and citizens is increasingly close. In this regard, the social impact of emergencies would continue to expand, and the scope of their impact would continue to expand. Sometimes, regional emergencies worsen in a short time, leading to a chain reaction. In this sense, if the public administration department cannot respond to the emergency quickly and effectively, its negative impact would continue to increase, causing more serious and deeper losses.

2.2. Psychological characteristics of civil servants

In emergencies, the psychological characteristics of civil servants mainly include the following. The first is physical symptoms. In an emergency, most civil servants suffer from insomnia and are weak. These physical symptoms often reflect unhealthy psychology that brings pain to civil servants. In addition, unhealthy lifestyles and habits have increased the burden on civil servants. The second is the imbalance of desire. In an emergency, civil servants often excessively pursue their own interests and needs, lack a sense of

FIGURE 1
Characteristics of public emergencies.

FIGURE 2
The dual role of civil servants' psychological pressure.
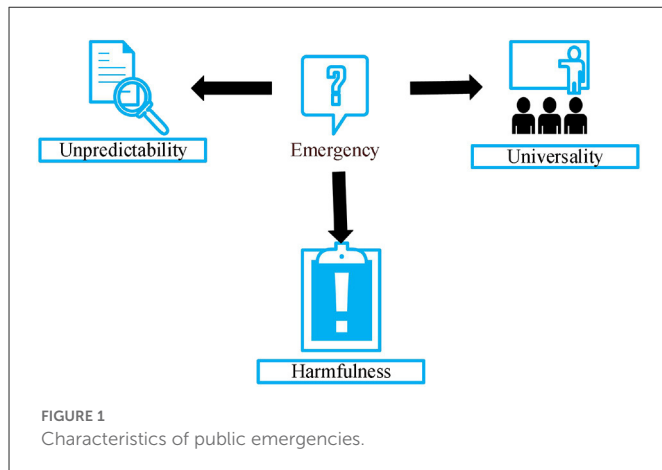
social morality, and lack a sense of security. They alsp have a strong sense of inferiority in psychology, cannot correctly treat the dignity of others, and use sarcastic language to describe the achievements of others. Although some civil servants have low positions and limited power, the wage gap between department employees is determined by increasing employment opportunities and expanding interpersonal relationships, resulting in some civil servants' psychological imbalance and desire for material benefits (13). The third is job weariness. Because of the complexity of work and emergency situations, civil servants often feel depressed and negative. Their interest and enthusiasm in work have decreased, and their activity and creativity have decreased. Their attention and memory have weakened, and their spirit and working state are also poor. When encountering difficulties and setbacks in work, he is afraid of difficulties and dangers and indifferent to work, mainly by improving the psychological quality of government administrators. The fourth is fear. The overall quality of civil servants has been continuously improved, but the competition for emergency response has become increasingly fierce. The fierce competition has aroused the anger, anxiety and hesitation of officials. Moderate anxiety can improve the morale of civil servants, but excessive anxiety would affect their normal work and life, cannot handle state affairs satisfactorily, cannot tolerate the masses, or even cannot argue with the masses, which leaves a bad impression on the masses.

2.3. The dual role of the psychological pressure of civil servants

The psychological pressure generated by civil servants in emergencies has both positive and negative effects, as shown in Figure 2. The first is the positive effect. Under the maximum pressure, the range of high-performance work performance is the best pressure zone. In this regard, work must be carried out under personal pressure, while the business value in this area is relatively high. From an individual perspective, in areas where work pressure is more appropriate, people can exercise individual psychological endurance and encourage them to actively adjust their mentality (14). In the best pressure zone, civil servants work more actively. When they encounter problems in life and work, they would become more calm. From the perspective of organizational efficiency, if
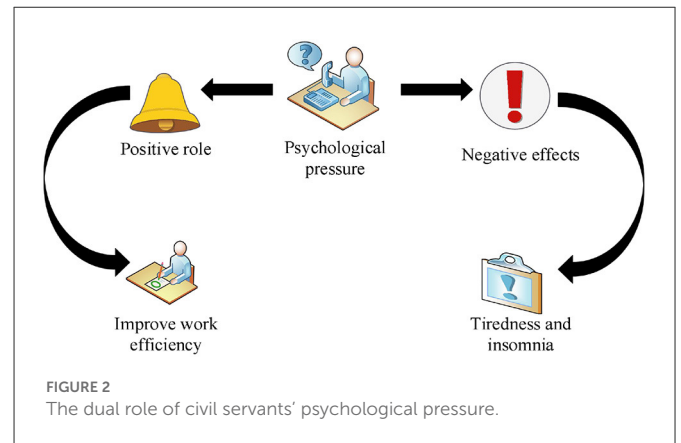
the workload is placed in a more appropriate environment, it can improve efficiency. The second is the negative impact. The pressure on employees exceeds the optimal pressure, which greatly reduces the work efficiency of employees. In particular, the workload is too small, and the working conditions are too good. It is difficult to mobilize the enthusiasm of civil servants, resulting in a significant reduction in the enthusiasm and concentration of staff, which greatly reduces the efficiency of civil servants. If the pressure is high, officials may lose sleep. When the pressure exceeds the critical point, civil servants would feel tired.

3. Psychological adjustment and intervention measures of civil servants in public emergencies

3.1. The necessity of psychological adjustment of civil servants in emergencies

First, the development trend of public emergencies has brought new challenges. With the destruction of the natural environment, the acceleration of population and social mobility, the deepening of the market mechanism and the transformation of societies in various countries, the occurrence of natural disasters has not only increased, but also the number of social emergencies in the political, economic and social fields has increased, making these problems more and more difficult to solve. These unforeseeable social events not only pose a serious threat to people's lives, but also cause great damage to social economic development and social stability due to the outbreak of social events, because the deterioration of social events would affect the public's sense of trust in the government. At present, the main trend of events related to unforeseen social events is that the number of such events is increasing, and their impact is expanding. The frequency, scale and risk of unexpected social events are also increasing. It rapidly spreads the information of public emergencies, and expands the scope and increases the fluctuation frequency. It can also be seen that changes in emergencies seem to pose new challenges to the ability of civil servants to cope with emergencies. Second, emergency relief is an important task for civil servants who are responsible for responding to emergencies. Social crisis management is a dynamic process. Civil servants are the main body of national

FIGURE 3
Problems exposed by civil servants in response to emergencies.

FIGURE 4
Psychological intervention of civil servants in emergencies.
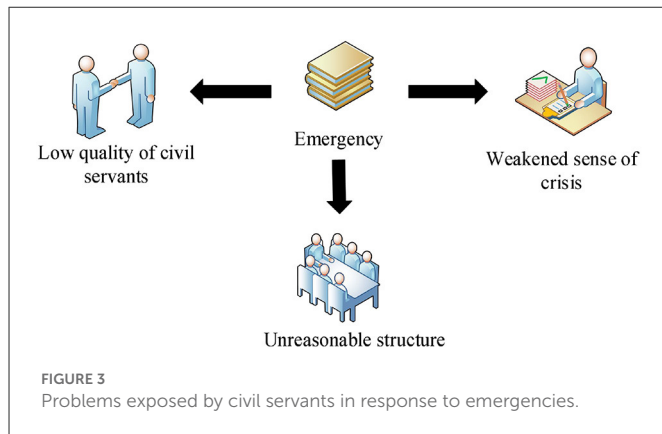
crisis management, controlling this dynamic process and managing the entire management process. Therefore, the crisis management ability of civil servants plays an important role in managing public crises. Civil servants usually assume corresponding political, management and work responsibilities and represent the image of the government or departments to some extent. They play an important role in emergency management. Civil servants are the focal points, advocates and executors of the government and senior management, as well as lawyers, decision-makers and crisis observers at the local level (15). The crisis is characterized by suddenness and universality, which puts forward higher requirements for the emergency response ability of civil servants. Timely and appropriately solving the national crisis that would undermine stability and unity can not only solve the problems that affect the daily life of citizens, but also bring much convenience to society and people. Therefore, the ability of civil servants to deal with emergencies must be strengthened.

3.2. Problems of civil servants in dealing with emergencies

There are mainly three kinds of problems exposed by civil servants when dealing with emergencies, as shown in Figure 3. First, the quality of civil servants is low. In general, the qualifications and qualities of civil servants meet the needs of public administration. However, in the emergency crisis, the mentality and behavior of civil servants are still insufficient, which indicates that they have some problems in coping with the crisis, mainly the confusion and psychological escape when dealing with emergencies. Second, the structure of the organization is unreasonable. The current national crisis management system mainly depends on the existing administrative power of governments at all levels, which affects the effectiveness of crisis management. The emergency preparedness is incomplete and the emergency work is not carried out. The administrative functions of the government are unbalanced, and the single emergency function and information communication are not timely. In emergencies, communication is an important task, and the role of non-governmental organizations has been weakened. In an emergency, society is not the object of passive mobilization. Mature societies can also mobilize actively in crisis situations, even before the government. Third, the sense of crisis
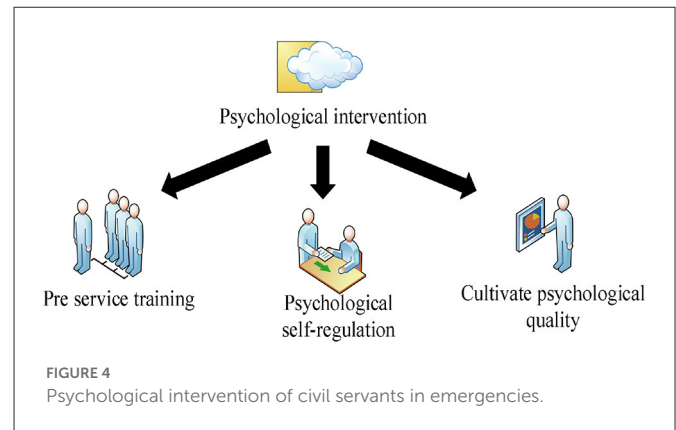
has weakened. The quality of some civil servants does not meet the actual needs. The most serious defect is the lack of awareness of the seriousness of social emergencies and the importance of crisis management, and the lack of understanding of the crisis management and management rules of social emergencies. Therefore, their awareness of ideological crisis is weak. They lack effective measures to prevent and deal with social emergencies stipulated by law, and their awareness and quality of dealing with emergencies are very poor.

3.3. Psychological intervention measures for civil servants in emergencies

The psychological intervention of civil servants in emergencies can be started from the following aspects, as shown in Figure 4.

(1) Pre-service training.

People need to guide civil servants to take up their posts, so that they have certain psychological expectations. In addition, a problem reporting center would be set up within the unit to provide information and advice to civil servants on work, family or psychological problems, actively promote and support the resolution of these psychological problems, and protect their privacy and sense of security. Most of them are biased against users of consulting services, which means that civil servants cannot receive timely medical care when mental health problems occur, and they lose confidence in senior managers and their stable work. To this end, the government and enterprises should regularly carry out psychological literacy activities so that civil servants can collectively solve psychological problems, mainly to improve the psychological endurance to deal with emergencies. In addition, the psychological problems of civil servants should not be disadvantaged, excluded from society or discriminated against. On the contrary, these problems need more care, help and warmth. In addition, in the work and daily life of civil servants, people must give them some positive evaluation and encouragement, promote mutual support and coordination between civil servants, make them closer to the psychological quality standards of civil servants, and expand their communication opportunities. This would not only improve their work efficiency, but also ensure a more harmonious interpersonal relationship between civil servants.

(2) Psychological self-regulation.

The first is to master the adaptability. If people decide to work in the civil service, people should be prepared mentally. The public sector faces many challenges, pressures and setbacks. In the face of failure, civil servants must overcome failure and recognize the nature of failure. Everyone would fail, and failure would not last forever. The psychological performance of civil servants would not continue to be weak after they are used to failure. If people feel depressed and anxious, people should avoid overloading, set priorities and the right date, leave room for maneuver, and find ways to relax. In addition, increasing physical activity can alleviate the physical symptoms of diseases and reduce the occurrence of psychological problems.

(3) Cultivating psychological quality.

First of all, people must provide high-quality psychological education for the government, society and individuals. In order to improve the psychological level of civil servants, social training institutions should look for psychologists and offer psychological training courses to cultivate the psychology of civil servants. Secondly, it is the positive influence of like-minded people, social environment and cultural media. The third is to help civil servants enhance their sense of identity and better serve the people by cultivating their psychological quality. Finally, people must consciously combine learning, career and personal life to develop strengths and eliminate weaknesses. People must further strengthen the psychological identity of civil servants, strengthen mutual trust and interaction between civil servants, and strengthen the unity and cooperation within the team through high-quality training for different groups.

4. Application of firefly algorithm in the psychological adjustment of civil servants

In order to study the psychological status of civil servants under emergencies and the specific effect of adjustment and response, this paper analyzes the psychological experience effect and actual psychological score of civil servants under emergencies through the firefly algorithm, and selects corresponding adjustment measures according to the scoring indicators, so as to improve the psychological quality of civil servants. Firefly algorithm calculates comprehensive evaluation index and prediction error through fitness function. First of all, this paper uses the firefly algorithm to propose a strategy to help civil servants improve their psychological quality:

$$A_i = A_i + \alpha(x) \times (A_j - A_i) + \beta \times \delta_i \tag{1}$$

$$\alpha(x) = \alpha_0 e^{xij} \tag{2}$$

Among them, Formula (2) refers to the attraction of high psychological quality to low psychological quality, and β, δ_i refers to the step size factor and random factor of improving psychological quality strategy. This paper then analyzes the adaptability function of civil servants' psychology under emergencies as follows:

TABLE 1 Satisfaction of civil servants in three regions with psychological intervention strategies.

	Satisfied	Commonly	Dissatisfied
Region 1	87	7	6
Region 2	85	6	9
Region 3	86	9	5
Total	258	22	20

$$\min y(S_i, T_i) = \sqrt{\frac{1}{m} \sum_{i=1}^{m} (a(i) - \hat{a}(i))^2} \tag{3}$$

S_i, T_i refers to the strategy of improving psychological quality and the effect of improvement, and m refers to the training strategy of psychological adjustment. Then it analyzes the evaluation effect and relevant evaluation indicators of the comprehensive quality of civil servants' psychological adjustment under emergencies:

$$Z = \sqrt{\frac{1}{m} \sum_{n=1}^{m} (a_n - \hat{a}_n)^2} \tag{4}$$

$$Q = \frac{\sum_{n=1}^{m} a_n \hat{a}_n}{\sqrt{\sum_{n=1}^{m} a_n^2} \sqrt{\sum_{n=1}^{m} \hat{a}_n^2}} \tag{5}$$

Then, according to the comprehensive evaluation effect and relevant evaluation indicators, the final prediction error value of civil servants' comprehensive psychological quality is:

$$R = Z \cdot \frac{\min y(a_n \hat{a}_n)}{Q} \tag{6}$$

5. Experimental evaluation of the psychological adjustment of civil servants in emergencies

In order to study the psychological changes and self-regulation of civil servants in emergencies, this paper analyzed the predictive value of the comprehensive psychological quality of civil servants' psychological adjustment and the comprehensive evaluation effect through the firefly algorithm, and made the corresponding psychological adjustment plan according to the comprehensive evaluation, so as to improve the psychological quality of civil servants. First of all, this paper investigated the satisfaction of civil servants in three regions with the psychological intervention strategies proposed in the paper, including 100 civil servants in each region, as shown in Table 1.

According to the data described in Table 1, civil servants in the three regions were generally satisfied with the psychological intervention strategies proposed in the paper. Among the satisfied civil servants, Region 1 had the most satisfied civil servants,

FIGURE 5
Civil servants' crisis awareness and emergency response ability under the implementation of psychological strategies.

FIGURE 6
Prediction error value and evaluation effect of civil servants' comprehensive quality.
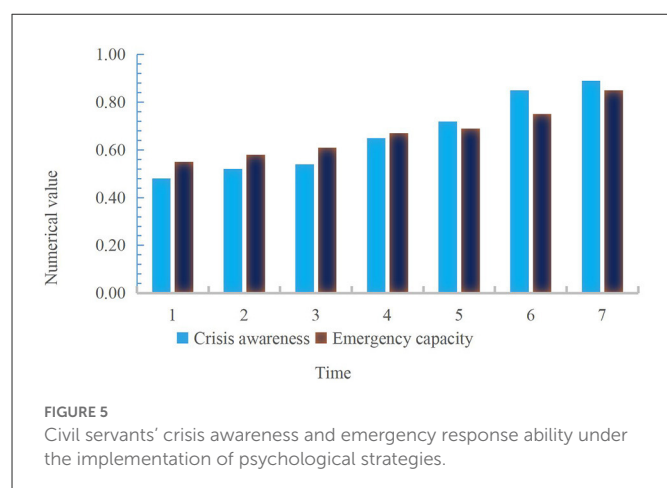
accounting for 33.7% of the total, and Region 2 had the least satisfied civil servants, accounting for 32.9% of the total. Among the general civil servants, the number of civil servants in Region 3 was the largest, accounting for 40.9% of the total, while the number of civil servants in Region 2 was the smallest, accounting for 27.3% of the total. Among the unsatisfied civil servants, the number of civil servants in Region 2 was the largest, accounting for 45% of the total number of unsatisfied civil servants, while the number of civil servants in Region 3 was the smallest, accounting for 25% of the total number of unsatisfied civil servants. On the whole, 86% of the total number of civil servants in the three regions were satisfied; 7.3% were generally satisfied; 6.7% were dissatisfied. Satisfied civil servants believed that the psychological intervention strategy can reduce the psychological infection of emergencies to them, and avoid the anxiety caused by their inability to deal with emergencies in time or well. The dissatisfied civil servants thought that the psychological intervention strategy did not help to improve the psychological quality, because they think their psychological endurance is no problem, and psychological treatment would affect their reputation. This paper then analyzed the crisis awareness and emergency response ability of civil servants under the implementation of psychological strategies. The specific changes of the two are shown in Figure 5.

According to the data described in Figure 5, under the implementation of psychological strategies, the crisis awareness and emergency response capacity of civil servants have gradually increased over time, with the average value of crisis awareness of civil servants being about 0.66 and the average value of emergency response capacity being about 0.67. On the whole, the initial value of civil servants' crisis awareness was 0.48, which increased to 0.89 on the seventh day, an increase of 0.41 in the whole process; the initial emergency capacity of civil servants was 0.55, which increased to 0.85 on the seventh day, an increase of 0.30 in the whole process. The increase of crisis awareness and emergency response ability of civil servants under the psychological intervention strategy showed that strong psychological quality can help civil servants improve their comprehensive quality and ability to cope with difficulties, and avoid negative emotions such as anxiety due to inability to solve problems. It not only improved the psychological endurance, but also improved the ability to solve emergencies. Then the firefly algorithm was used to analyze the prediction error value of the comprehensive quality of civil servants

FIGURE 7
Comprehensive psychological quality and psychological adjustment ability of civil servants after psychological intervention.
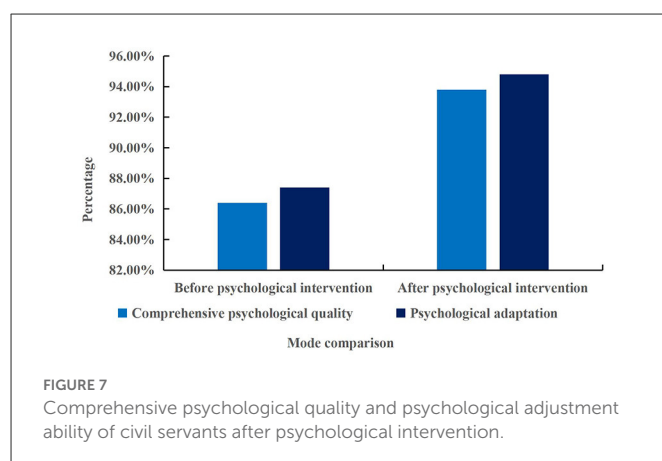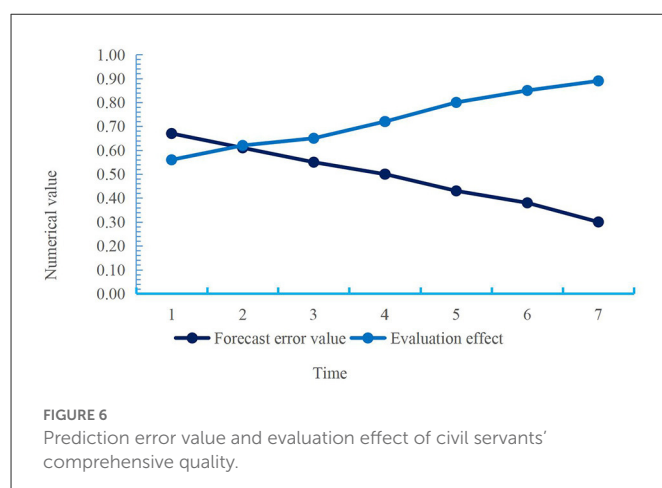
and the evaluation effect. The specific changes are shown in Figure 6.

According to the curve depicted in Figure 6, the prediction error value of civil servants' comprehensive quality was declining, while the evaluation effect of comprehensive quality was rising. The average value of the prediction error value of comprehensive quality was about 0.49, and the average value of the evaluation effect of comprehensive quality was about 0.73. In the whole process, the prediction error value of comprehensive quality decreased by 0.37, and the evaluation effect of comprehensive quality increased by 0.33. The decline of the prediction error value of comprehensive quality showed that the psychological detection of civil servants was more accurate after psychological intervention, which was convenient to guide their psychological development in a timely manner, mainly improving their psychological quality, and laying a foundation for the handling of future emergencies and social governance. The increase in the evaluation effect of comprehensive quality showed that the overall quality and ability of civil servants to deal with emergencies have become stronger and stronger after psychological intervention. Finally, the comprehensive psychological quality and psychological adjustment ability of civil servants after psychological intervention were analyzed and compared with the data before psychological intervention, as shown in Figure 7.

According to the comparison chart in Figure 7, the comprehensive psychological quality and psychological adjustment ability of civil servants after psychological intervention were better than those before psychological intervention. The comprehensive psychological quality of civil servants after psychological intervention was 8.56% higher than that before psychological intervention, and the psychological adjustment ability was 8.47% higher than that before psychological intervention. The implementation of psychological intervention strategy can improve the psychological endurance of civil servants, and make them always maintain a positive and objective attitude to face various difficulties, and would not give up because of setbacks. Through the psychological intervention strategy, the adaptability and psychological status of civil servants were better than before the psychological intervention, and the overall quality of civil servants has also improved a lot.

6. Conclusions

Public emergencies not only contribute to the psychological development and psychosocial optimization of civil servants, but also have a negative impact on their mental health and psychosocial optimization. Today's social reality is like a double-edged sword. On the one hand, it provided more opportunities for civil servants to realize themselves and develop their potential, and promoted their mental health and sound social thinking; on the other hand, the rapid changes in society have increased the psychological pressure of civil servants, posed an actual or potential threat to their mental health, and caused many problems to their psychosocial situation, thus making it more difficult for civil servants to adapt. This is a greater demand for the psychological skills of civil servants and a major challenge to the provision of psychosocial services. The analysis of the psychological problems faced by civil servants provides information about psychological intervention and lays a foundation for strengthening the emergency response capacity of civil servants.

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

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.

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Exploration on the optimization of occupational injury and employment protection of takeout workers in the context of public health

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With the acceleration of the pace of urban life and the development of information technology, the takeout industry has emerged as the times require, which obtains intermediate costs by distributing goods to consumers. People pay more and more attention to public health, which requires takeout workers to drive as fast as possible to ensure the quality and safety of goods, but it also makes takeout workers suffer from various occupational injuries, such as car accidents, stomach diseases caused by eating disorders and long-term psychological pressure. This paper optimized the employment protection of takeout workers in combination with their professional characteristics. This paper used the analytic hierarchy process (AHP) to analyze the indicators that can evaluate the optimization effect of employment protection for takeout workers, and compared the occupation of takeout workers before and after employment protection. The experimental results showed that in Meituan takeout, the rationality of the average delivery management system before and after the optimization of employment protection was 47.2 and 64.4%, respectively; in ELEME takeout, the rationality of the average takeout distribution management system before and after the optimization of employment protection was 55.0% and 69.8%, respectively. Therefore, in the context of public health, the implementation of social security, employment relationship and optimization of service evaluation mechanism for outbound sales personnel can effectively improve the rationality of the delivery management system.

KEYWORDS

occupational injury, employment protection optimization, takeaway employees, public hygiene, analytic hierarchy process

1. Introduction

People's living standards are improving, and their lifestyles have undergone tremendous changes. Many young people, Baoma and migrant workers are more inclined to obtain the goods they need through special delivery due to high work pressure or lack of conditions to cook. With the continuous development of Internet technology, and the growing demand for people to sell and distribute, the takeout industry came into being. Taking out belongs to the service industry. It mainly refers to the services that businesses provide all the goods that can be delivered, including food distribution, water delivery and door-to-door repair. The takeout workers provided convenience for people's lives, which accelerated the development of the tertiary industry and met people's needs in life. However, the takeout employees need to deliver goods as quickly as possible, which leads to frequent accidents of takeout employees, and there is no relevant occupational risk guarantee for the injury of takeout employees.

When the takeout employees fail to complete the specified quantity, they would be dismissed. The takeout employees lack employment protection. In recent years, the takeout industry has developed rapidly. According to relevant statistics, China has the largest number of takeout workers in the world. In 2020, there were 16 million takeout workers, 90% of whom were men and 10% are women. The takeout workers have promoted the economic development, but their own occupational injuries are from many sources, and their occupations cannot be guaranteed stably. By optimizing the employment protection of takeout employees, reducing the occupational injury of takeout employees, and strengthening the employment relationship between takeout employees and the takeout platform, the employment of takeout employees can be guaranteed. The takeout industry is a new type of business, which protects the labor rights and interests of takeout personnel through targeted occupational protection. Therefore, this paper has research significance.

The rapid development of Internet technology has created many emerging industries, and many people have conducted in-depth research on the occupational injuries of people in emerging industries. Fischer (1) analyzed the work and rest situation and occupational risks of the takeout workers, and the research showed that: the long-term physical, mental and muscle fatigue of the takeout workers is the main reason for the occupational injuries of the takeout workers. Kearney et al. used meta-analysis to systematically analyze the risks of physical and psychological injuries affecting nursing staff. Through the investigation of occupational injuries among 1,000 nursing staff, it was found that the risk of occupational injuries among nursing staff was increasing year by year (2). New-Aaron (3) made detailed statistics on the occupational injuries and deaths of workers in the United States. The results showed that 44% of agricultural injuries were fatal. Clouser interviewed Latino farm workers to analyze the reasons that affect the occupational injury risk of Latino farm workers. Among them, work pressure, unfair supervisors and inability to communicate fluently in Spanish language were the main reasons for Latino farm workers' occupational injury (4). By analyzing the occupational injuries of employees, the main causes of occupational injuries of employees can be calculated. However, there is a lack of targeted optimization of employment protection for occupational injuries of employees.

With the improvement of people's living standards, more and more attention has been paid to the employment protection of the bottom personnel. Many people have conducted in-depth research on the optimization of the employment protection of takeout workers. Dessaint et al. (5) pointed out that the implementation of the employment protection policy effectively prevented the enterprises from arbitrarily cutting jobs and provided employment security for employees. Passaretta et al. (6) analyzed the employment of employees in the European labor market. Long term labor contracts can ensure stable employment of workers. Vornholt analyzed the occupational injuries and employment status of the disabled. The study pointed out that the disabled are important labor resources in the labor force, and they need to be optimized for employment protection to stabilize their employment (7). Although the optimization of employment protection for workers can improve the occupational safety and stability of workers, it is rare to compare the employment situation of workers before and after the optimization of employment protection.

FIGURE 1
Examples of occupational injuries of takeout employees.
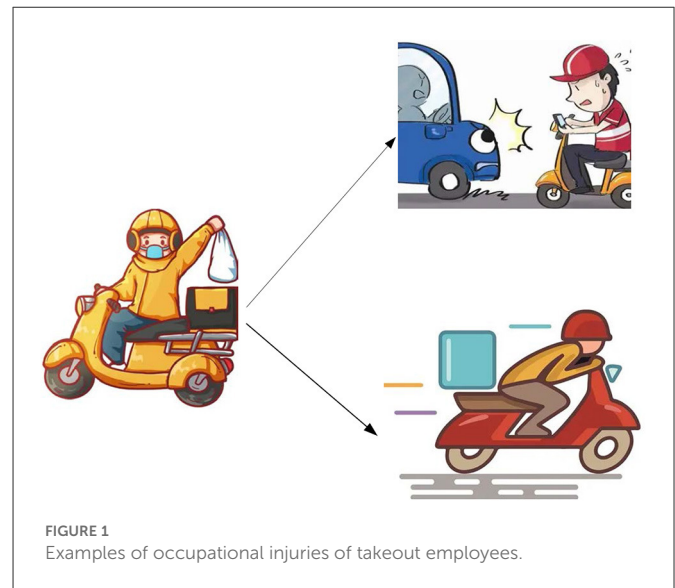
The appearance of takeout platform has satisfied the development of urban fast-paced life and provided employment for a large number of urban migrant workers, but the occupational injury of takeout employees is huge. This paper optimized the employment protection according to the characteristics of occupational injuries of takeout workers, and compared the employment protection of takeout workers before and after the optimization. The results showed that the optimization of employment protection can reduce the psychological pressure of takeout workers.

2. Optimization method of employment protection for takeout employees

In order to cope with the fast-paced life demand, many new business forms have emerged under the development of the Internet. The new business forms are characterized by flexible employment and simple work content, which provide employment options for a large number of people who do not know what to do. It has attracted a large number of practitioners. The employees of the new business include delivery personnel, express delivery personnel and online car hailing drivers, which provide life services for the development of society. Among them, takeout workers account for the largest proportion. The way of work liberalization enables takeout workers to arrange their working hours flexibly, but the vast majority of takeout workers compete with time, which also indirectly leads to occupational injuries of takeout workers. The examples of occupational injuries of takeout workers is shown in Figure 1.

Figure 1 shows examples of occupational injuries of takeout workers. All takeout workers compete with time in the process of delivering meals. Falling down or sudden death due to high fatigue are common occupational injuries of takeout workers.

With the continuous development of information technology, the takeout platform led by Meituan and ELEME quickly occupied the catering market, which provide a convenient life for urban residents. In addition, it provides businesses with more opportunities, and also provides more urban migrant workers with a job opportunity. However, with the development of takeout platforms,

FIGURE 2
Public health service architecture.
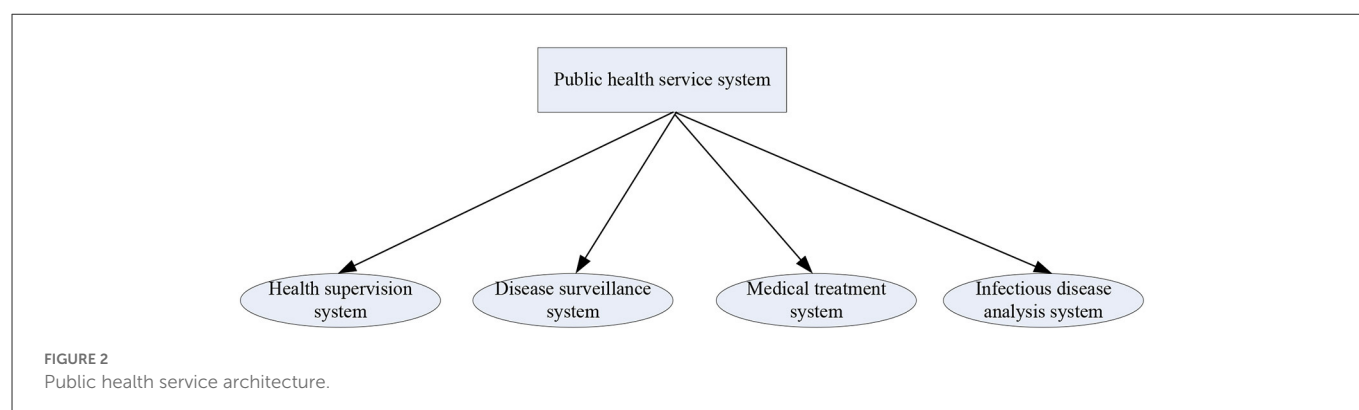
the competition between takeout platforms is becoming more and more fierce, and the takeout management system is becoming more and more rigorous. As a service worker, the takeout workers should meet all the requirements of customers and ensure the delivery quality and speed of goods within the specified time. The strict management of takeout employees on the takeout platform makes it very easy for takeout employees to cause occupational injuries in the struggling working environment, which is an extremely unfair system for takeout employees (8).

2.1. Public health

Public health is to analyze the population, and study the law of the impact of environment on health through mature medical means, so as to analyze the relationship between social environment and human health, and find out ways to improve population health (9, 10). Public health measures can achieve the goal of controlling diseases and protecting people's health.

Environmental sanitation is to analyze the impact of community environment on human health, and determine the main environmental factors that affect people's lives by subdividing their living environment. On the basis of making full use of beneficial environmental factors and controlling harmful environmental factors, it puts forward hygiene requirements and preventive measures, which can improve human health and the health level of the whole population.

Occupational health mainly analyzes the impact of occupational environment on labor health. Through the analysis of different occupational environments, it can create a more comfortable working environment for workers, and try to meet the physical and psychological needs of workers, so that workers can achieve the best state at work.

Public health, environmental health and occupational health play a more and more important role in protecting and promoting people's health and preventing diseases, and are the basis of disease prevention and control activities. The public health service architecture is shown in Figure 2.

Figure 2 depicts the public health service architecture. The public health system is divided into four subsystems: health supervision system, disease detection system, medical treatment system, and infectious disease analysis system.

Public health needs to control population health or disease prevalence. It analyzes the distribution of diseases in different populations, time and space, and analyzes and intervenes on the future development trend of diseases (11, 12). It analyzes the impact of living environment and genetic genes on human health, and analyzes the protein genes that affect human health functions from the perspective of biological genes. It analyzes the living environment, daily diet and living rules of the human body, and explores the impact of life factors of the population on human health, so as to propose corresponding protection measures.

In the fast-paced urban life, people often have no time to cook because of the compact work content. For office workers, takeout has become the first choice to solve the problem of eating. Takeout food has become a necessity in people's daily life. Therefore, the hygiene problem of takeout food needs to be attached great importance. Public health has strict rules and regulations for ensuring the hygiene of takeout food.

The takeout workers need to confirm the food temperature when delivering food, and deliver the takeout to consumers when the temperature is kept. In the process of food production, storage and transportation, the staff must pass physical examination to obtain health certificates. The delivery staff participate in the food transportation, so health certificates are also necessary. Take away stores need to be open to the outside world so that consumers have the right to know. At the same time, it is necessary to supervise the takeout stores to ensure food safety.

2.2. Optimization of occupational injury and employment protection

Occupational injury refers to the injury or accident suffered by employees in the process of carrying out work or activities related to their occupation (13, 14). As an emerging industry, the takeout industry provides convenience for people's lives and also provides a job for urban migrant workers. However, the problem of occupational injuries among employees is becoming more and more serious (15).

The takeout food industry has developed in recent years. The main job of the takeout workers is to deliver the goods from the merchants to the consumers safely and on time. Such a simple delivery task should not cause frequent occupational injuries. The main reasons for frequent occupational injuries among takeout employees are.

The delivery management system is not comprehensive enough. In some non-meal time, the delivery staff need not rush to deliver, and the traffic environment is also very smooth. However, in the peak

FIGURE 3
Model diagram of occupational injury and employment protection optimization of takeout employees.

FIGURE 4
Structure model diagram of AHP.
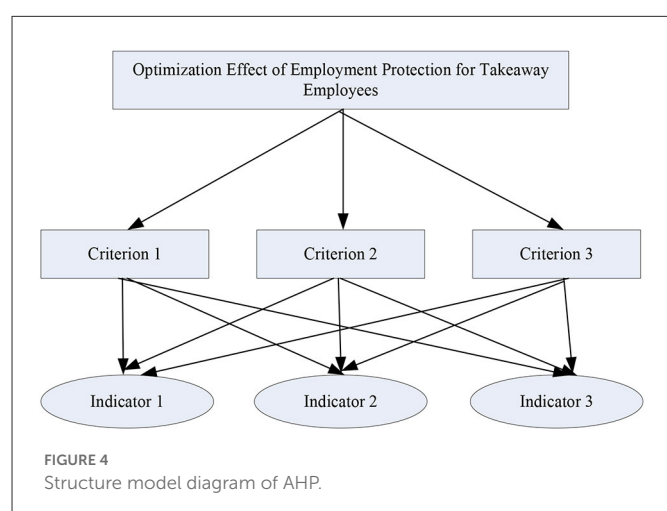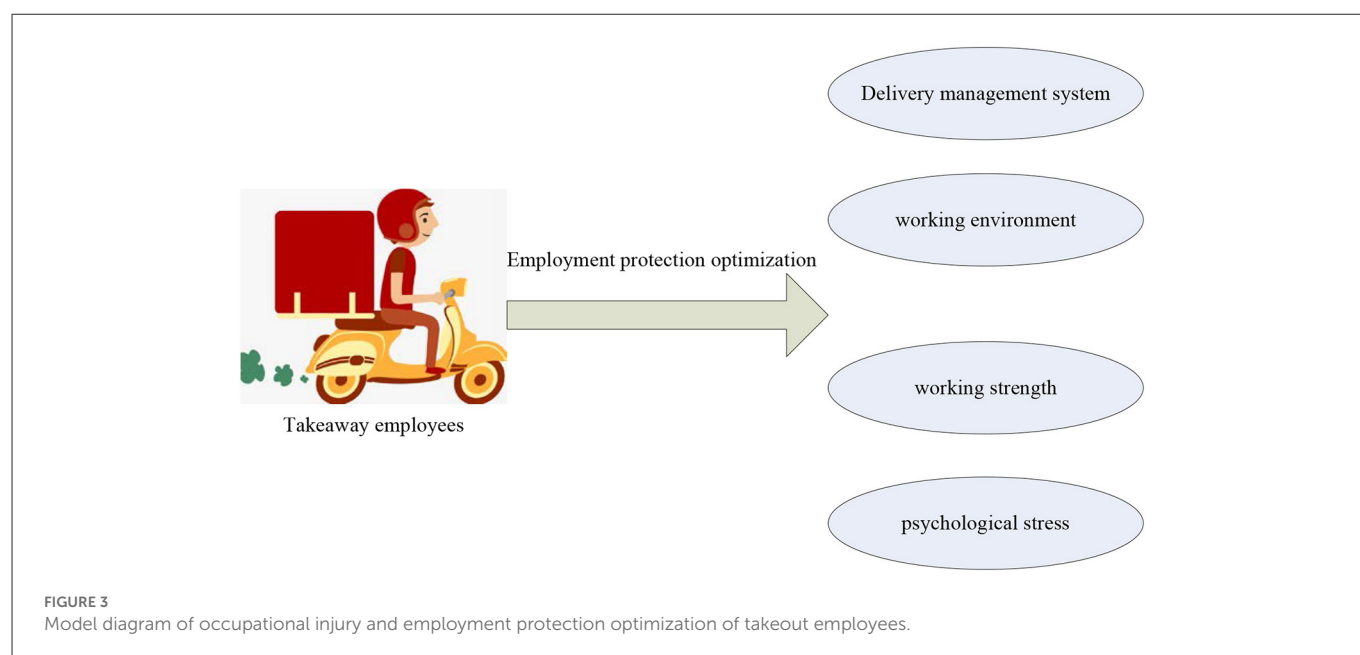
meal time, a delivery clerk would send seven to 10 meals in a short time, which forces the delivery clerk to ride fast on the road (16). In addition, takeout riders often violate traffic rules in order to rush, which indirectly leads to accidents among takeout employees.

The working environment is bad, and the threshold of the delivery industry is very low. However, if the delivery clerk wants to earn a considerable economic income, he must work for a long time. The delivery environment is very bad. Generally speaking, the vast majority of consumers order takeout because of the bad weather, so the takeout workers must deliver in the hot, windy and rainstorm environment. Working in such bad conditions also increases the risk of the takeout workers.

The work intensity is high. The takeout workers do not only work at breakfast, lunch and dinner. Many takeout workers work for more than 10 h a day. For such intensive work, takeout workers often cannot eat on time. Many takeout workers have stomach problems of varying degrees.

The psychological pressure is high. As a kind of service industry, the evaluation of consumers would directly affect the work performance of takeout practitioners. Many takeout workers try to seize the time to provide the best service for consumers. However, in the long run, takeout workers are under great psychological pressure. When consumers comment on business trips, takeout workers would not only face fines, but may even face resignation.

Employment is the result of mutual search between labor supply and demand. The takeout industry has provided a large number of jobs to the society and solved the employment problem of many people. However, the employment relationship between takeout employees and the takeout platform is not stable, and the occupational injury of takeout employees is also closely related to employment protection. It is necessary to optimize the employment protection of takeout workers and improve the employment stability of takeout workers, so as to reduce the frequency of occupational injuries. The optimization model of occupational injury and employment protection of takeout employees is shown in Figure 3.

Figure 3 describes the optimization model of occupational injury and employment protection of takeout workers. Through the optimization of employment protection, the management system of delivery can be adjusted and the working environment can be improved. It can also adjust the work intensity and reduce the psychological pressure of takeout employees.

For the occupational injuries of takeout employees, the following aspects can be optimized for employment protection:

Social security optimization: because of the great mobility of takeout employees, many takeout employees have not received the social insurance paid by the takeout platform, which is very unfavorable for employees engaged in fatigue industries. Therefore, the internship period for takeaway workers can be reduced, and social insurance can be provided for takeaway workers as early as possible.

Employment relationship optimization: generally, the takeout platform employs riders from third-party companies, which makes the employment relationship between the takeout platform and riders unstable. This causes many takeout practitioners to be dismissed

by the platform. It is necessary to strengthen the employment relationship between the takeout platform and riders.

Service evaluation mechanism optimization: traditional takeout platforms attach great importance to the evaluation of consumers. Although this is a means to respect the rights and interests of consumers, it is too harsh for takeout practitioners, and some consumers would maliciously give travel evaluations, which seriously affects the performance of takeout workers. The service evaluation mechanism needs to be optimized. The platform should make a correct investigation on the evaluation of bad comments, and should not blame all the takeout practitioners.

2.3. AHP

AHP is an analytical method that combines quantitative and qualitative analysis. It determines the impact indicators by refining the solution to the problem, and then analyzes the indicators [17, 18]. AHP can solve complex logic problems, and is very suitable for analyzing the factors that affect the optimization effect of employment protection for takeout workers. The structure model of AHP is shown in Figure 4.

Figure 4 is the structure model of the AHP. The overall structure is divided into three layers. Among them, the criterion layer is a rough analysis of the optimization effect of the employment protection of the selling employees, and the indicator layer is a detailed analysis of the optimization effect of the employment protection of the selling employees.

It is supposed that in the system that affects the optimization effect of employment protection for takeout workers, the indicator layer is $D = \{d_1, d_2, \ldots, d_n\}$, then the equation for the comparison of the impact of any two indicators on the optimization effect of employment protection is:

$$d_{ij} = \frac{d_i}{d_j}. \tag{1}$$

In Equation (1), d_i represents the i-th indicator, and d_j represents the j-th indicator. The value range of i and j is $\{1, 2, \cdots, n\}$.

All indicators are compared in pairs and a judgment matrix is constructed.

$$Q = \begin{bmatrix} 1 & d_{12} & \cdots & d_{1n} \\ d_{21} & 1 & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & 1 \end{bmatrix}. \tag{2}$$

In Equation (2), each column of the matrix can be regarded as the relative weight of the indicator.

Before using the judgment matrix to calculate the relative weight of each indicator in the AHP, it is necessary to analyze the consistency of the judgment matrix [19, 20].

The consistency indicator is calculated as:

$$CI = \frac{t_{\max} - n}{n - 1}. \tag{3}$$

In Equation (3), CI represents the consistency index, and $t_{\max}$ represents the maximum eigenvalue of the judgment matrix.

The consistency ratio is expressed as:

$$CR = \frac{CI}{RI}. \tag{4}$$

In Equation (4), CR represents the consistency ratio. RI represents the random consistency index corresponding to the judgment matrix.

When $CR < 0.1$, it means that the judgment matrix is consistent, and the weight of the indicator can be calculated by using the judgment matrix [21]. When $CR \geq 0.1$, it means that the judgment matrix does not have consistency and needs to be re planned.

The relative weight of indicators is expressed as:

$$w_i = \frac{d_{1i} + d_{2i} + \cdots + d_{ni}}{n}. \tag{5}$$

In Equation (5), w_i represents the relative weight of the i-th indicator.

3. Experiment on optimization of employment protection for takeout employees

3.1. Construction of the optimized evaluation system for the employment protection of takeout employees

The occupational injury of takeout employees is serious, and it is necessary to optimize the employment protection of takeout employees. In order to effectively analyze the effect of the optimization of employment protection, this paper used the AHP to build an evaluation system for the optimization of employment protection, and conducted a questionnaire survey on 200 takeout workers, which mainly investigated the indicators that they thought can evaluate the optimization effect of employment protection. The results of the questionnaire survey are shown in Table 1. The results of the questionnaire will be used as the basis for the analysis of the optimization of the employment protection of takeaway workers.

Table 1 describes the questionnaire results of the evaluation indicators of employment protection optimization. A total of four indicators have been calculated, of which the rationality of the delivery management system accounted for 28% at the highest; the proportion of work intensity was 26%, and the proportion of psychological stress was at least 22%.

Since the indicators analyzed in the questionnaire cannot determine the weight of each indicator, the weight of each indicator is determined by constructing a judgment matrix. The weight of the optimization evaluation index of employment protection is shown in Table 2.

Table 2 describes the relative weights of each indicator. The rationality of the delivery management system accounted for the highest weight of 32%; the weight of work environment comfort was 28%, and the weight of psychological stress was at least

TABLE 1   Questionnaire results of the evaluation indicators of employment protection optimization.

Serial number	Evaluating indicator	Number of people (persons)	Percentage
1	Rationality of delivery management system	56	28%
2	Comfort of working environment	48	24%
3	Working strength	52	26%
4	Psychological stress	44	22%

TABLE 2   Weights of employment protection optimization evaluation indicators.

Target	Evaluating indicator	Index weight
Optimization effect of employment protection	Rationality of delivery management system	32%
	Comfort of working environment	28%
	Working strength	22%
	Psychological stress	18%

18%. Since the weight difference of these four indicators is not very large, these four indicators can all be used as indicators to evaluate the optimization effect of employment protection for takeout workers.

3.2. Experimental design for optimization of employment protection of takeout employees

In order to effectively analyze the effect of the optimization of employment protection for takeout employees, this paper compared the occupational injuries of takeout employees before and after the optimization of employment protection, as well as the impact on takeout employees. In order to effectively compare the optimization effect of employment protection for employees engaged in outbound sales, the main outbound sales platforms in China were analyzed. Meituan takeout and ELEME takeout occupy the takeout market in China. Therefore, this paper randomly selected 100 Meituan takeout employees and 100 Lulemao takeout employees as the objects of experimental comparison before and after the optimization of employment protection.

The takeout employees selected in the experiment did not know about this experiment in advance and worked normally during the experiment. The comparison points before and after the optimization of the employment protection for takeout employees are: the rationality of the delivery management system, the comfort of the working environment, the work intensity and the psychological pressure. In order to make the comparison before and after the optimization of the employment protection of takeout employees more sufficient, the experiment conducted data statistics on selected experimental personnel 5 months before and 5 months after the optimization of the employment protection. The frequency of data statistics was once a month. The purpose of this was to make the data of the optimization of the employment protection of takeout employees more detailed, so as to prevent external factors from interfering with the experiment.

4. Results of optimization of employment protection for takeout employees

4.1. Rationality of delivery management system

The traditional delivery management system is mainly based on the quantity of delivery orders, which allows the delivery practitioners to deliver as many goods as possible in a short time. The rationality of the delivery management system is closely related to the occupational injuries of the delivery employees. The rationality of the delivery management system before and after the optimization of employment protection was compared. The comparison results are shown in Figure 5.

Figure 5A is a comparison of the rationality of the Meituan delivery management system before and after the optimization of employment protection. The rationality of the delivery management system before the optimization of employment protection reached a minimum of 42% in the fifth month and a maximum of 56% in the third month. The rationality of the average delivery management system was 47.2%. However, the rationality of the delivery management system after the optimization of employment protection was continuously improved, from 58% in the first month to 70% in the fifth month, and the average rationality of the delivery management system was 64.4%. Figure 5B is a comparison of the rationality of the delivery management system before and after the optimization of employment protection. The rationality of the delivery management system before the optimization of employment protection fluctuated continuously during the experimental period; it reached a minimum of 46% in the third month and a maximum of 62% in the second month. The rationality of the average delivery management system was 55.0%. The rationality of the delivery management system after the optimization of employment protection reached a minimum of 66% in the second month and a maximum of 74% in the fifth month. The rationality of the average delivery management system was 69.8%. The continuous improvement of the rationality of the delivery management system after the optimization of employment protection may be due to the reduction of the
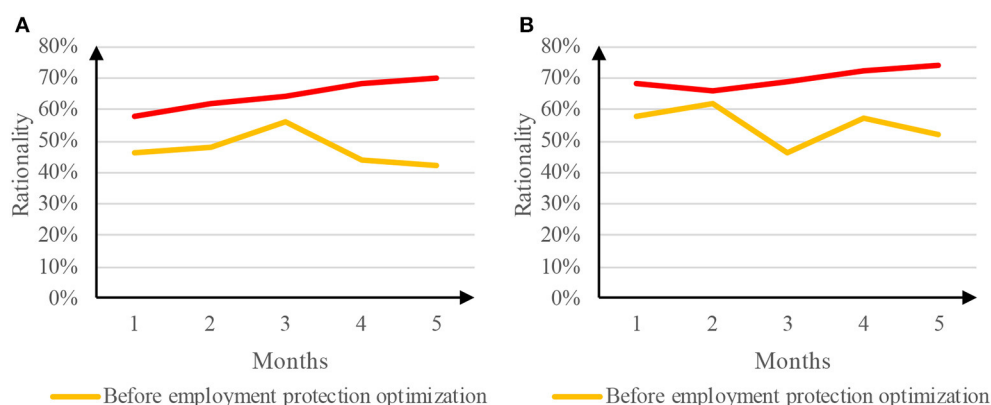
FIGURE 5
Comparison of rationality of delivery management system. **(A)** Rationality of Meituan takeout distribution management system. **(B)** Rationality of ELEME takeout distribution management system.
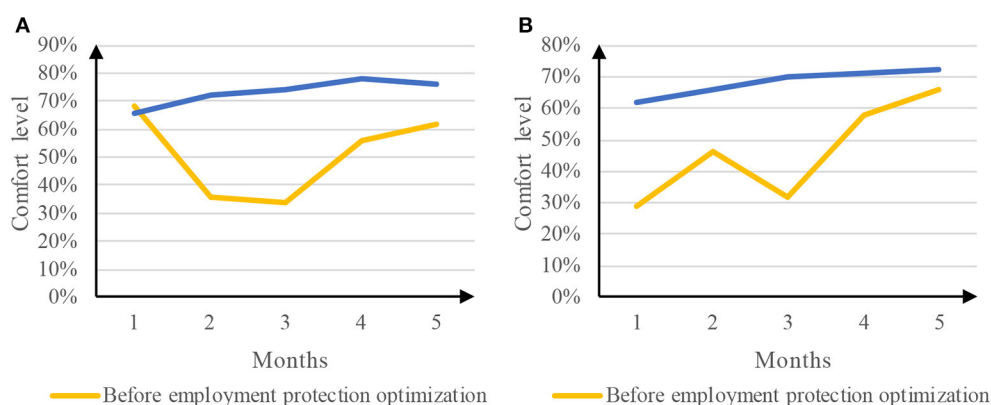
FIGURE 6
Comparison results of working environment comfort. **(A)** Comfort of Meituan takeout working environment. **(B)** Comfort of ELEME takeout working environment.
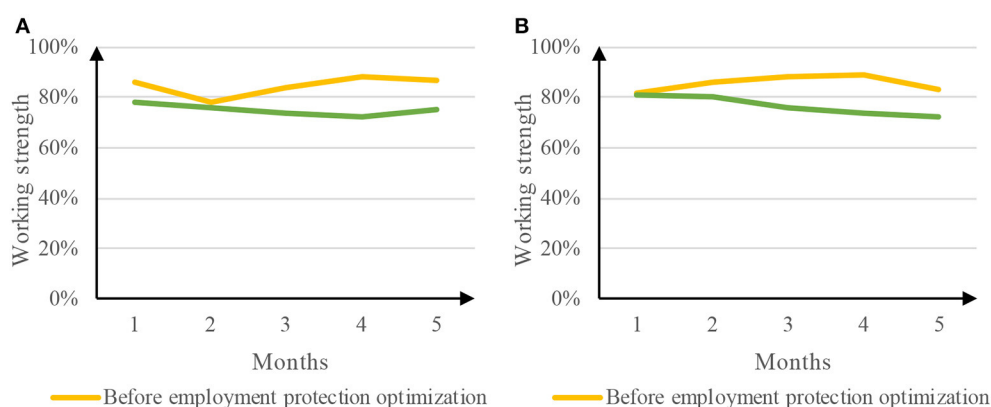
FIGURE 7
Comparison results of work intensity. **(A)** Work intensity of Meituan takeout. **(B)** Work intensity of ELEME takeout.

delivery volume requirements of the delivery platform. Therefore, the optimization of the employment protection of takeout employees can effectively improve the rationality of the delivery management system.

4.2. Comfort of working environment

The working environment of takeout employees is the main cause of occupational injury, and takeout distribution under high
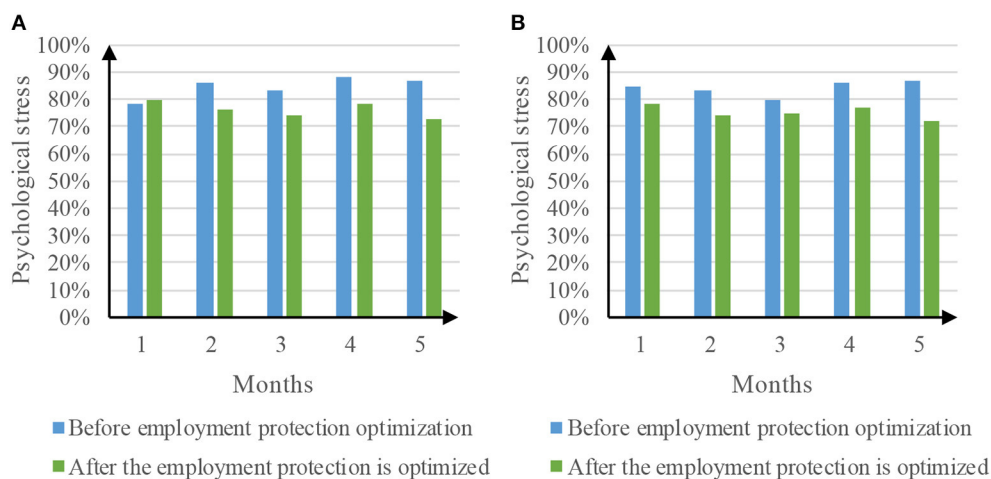
temperature and strong wind is prone to risk. The comfort of working environment before and after the optimization of employment protection was compared. The comparison results are shown in Figure 6.

Figure 6A is a comparison of the comfort level of Meituan takeout working environment before and after the optimization of employment protection. Among them, the comfort level of the takeout working environment before the optimization of employment protection reached a minimum of 34% in the third month and a maximum of 68% in the first month. The average comfort level of the takeout working environment was 51.2%. The poor comfort of the takeout working environment in the second and third months may be caused by bad weather. After the optimization of employment protection, the comfort level of the takeout working environment reached a minimum of 66% in the first month and a maximum of 78% in the fourth month. The average comfort level of the takeout working environment was 73.2%. Figure 6B is a comparison of the comfort level of the takeout working environment before and after the optimization of employment protection. Before the optimization of employment protection, the comfort level of takeout working environment reached a minimum of 29% in the first month and a maximum of 66% in the fifth month. The average comfort level of takeout working environment was 46.2%. After the optimization of employment protection, the comfort level of the takeout working environment was constantly improving, The comfort level of the takeout working environment increased from 62% in the first month to 72% in the fifth month, and the average comfort level of the takeout working environment was 68.2%. Therefore, employment protection optimization can effectively improve the comfort of the takeout working environment.

4.3. Working intensity

The work intensity of takeout employees is very high, and the daily delivery volume is very large. In order to complete the task, the delivery employees must improve the delivery speed, which causes many takeout employees to be in danger in the delivery process.

The work intensity before and after the optimization of employment protection was compared. The comparison results are shown in Figure 7.

Figure 7A is a comparison of the intensity of Meituan takeout before and after the optimization of employment protection. The takeout work intensity before the optimization of employment protection reached a minimum of 78% in the second month and a maximum of 88% in the fourth month, with an average work intensity of 84.6%. After the optimization of employment protection, the takeout work intensity reached a minimum of 72% in the fourth month and a maximum of 78% in the first month, with an average work intensity of 75.0%. Figure 7B is a comparison of the intensity of takeout before and after the optimization of employment protection. Before the optimization of employment protection, the takeout work intensity reached a minimum of 82% in the first month and a maximum of 89% in the fourth month, with an average work intensity of 85.6%. After the optimization of employment protection, the intensity of takeout was decreasing, from 81% in the first month to 72% in the fifth month, with an average intensity of 76.6%. Therefore, employment protection optimization, such as strengthening employment relationship, can effectively reduce the work intensity of takeout employees.

4.4. Psychological pressure

The performance of takeout employees is directly linked to the evaluation of consumers, which also makes the psychological pressure of takeout employees very high. Efforts are made to improve the delivery speed to obtain the praise of consumers, and the negative evaluation of consumers has a great impact on takeout employees. Long term psychological stress would make the takeout workers become depressed, and they often do not eat and drink on time in order to rush, which is very easy to cause stomach disease. The comparison of psychological pressure before and after the optimization of employment protection is shown in Figure 8.

Figure 8A is a comparison of the psychological pressure of Meituan takeout before and after the optimization of employment

protection. Before the optimization of employment protection, the psychological pressure of takeout work reached a minimum of 78% in the first month and a maximum of 88% in the fourth month. The average psychological pressure of work was 84.4%. After the optimization of employment protection, the psychological pressure of takeout work reached a minimum of 73% in the fifth month and a maximum of 80% in the first month. The average psychological pressure of work was 76.2%. Figure 8B shows the comparison of psychological pressure of taking out food before and after the optimization of employment protection. Before the optimization of employment protection, the psychological pressure of takeout work reached a minimum of 80% in the third month and a maximum of 87% in the fifth month. The average psychological pressure of work was 84.2%. After the optimization of employment protection, the psychological pressure of takeout work reached a minimum of 72% in the fifth month and a maximum of 78% in the first month. The average psychological pressure of work was 75.2%. Therefore, the optimization of employment protection through service evaluation mechanism can significantly reduce the psychological pressure of takeout employees.

5. Conclusions

In recent years, the accidents of takeout workers have occurred frequently, and the occupational injuries and employment security of takeout workers have received extensive attention. As a service industry, the core of takeout industry is to focus on the rights and interests of consumers, which makes takeout practitioners very hasty when distributing takeout food. Accidents are very easy to occur in the road sections with complex traffic, and the long-term and compact distribution tasks cause great physical and psychological damage to the takeout employees. This paper analyzed the professional characteristics of the takeout workers, and optimized the social security, employment relationship and service evaluation mechanism of the takeout workers. This paper also used the AHP to build an evaluation system for the optimization of the employment protection of takeout workers, and compared it before and after the optimization. The results showed that the optimization of employment protection can effectively improve the rationality of the delivery management system, the comfort of the working environment, and reduce the work intensity and psychological pressure at work. The optimization of employment protection can reduce the occupational injury of takeout workers and ensure the occupational safety of takeout workers. However,

this article analyzes the changes before and after the employment protection of the takeaway workers from four aspects, and makes a reasonable comparison of the work intensity of the takeaway workers, but lacks a comparison of the occupational injury of the takeaway workers. Therefore, through the questionnaire survey of more takeout employees, the analysis of objective indicators that can evaluate the optimization effect of employment protection for take-away workers would be the direction of future research.

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

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.

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Community home elderly care services, multidimensional health and social participation of chronically ill elderly—Empirical analysis based on propensity score matching and multiple mediation analysis

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Introduction: In recent years, China's aging process has deepened rapidly, the disease spectrum of the population has undergone major changes, the proportion and scale of elderly patients with chronic diseases are growing rapidly, and the multidimensional health problems of the chronically ill elderly are prominent, seriously affecting the participation of the chronically ill elderly in family, community, and social development. In response, China has implemented the "active response to population aging strategy," accelerated the development of community home elderly care services, and encouraged the chronically ill elderly to continue to play a role through social participation. So how does the community-based home-based medical care service affect the social participation of the chronically ill elderly? Is an important subject.

Methods: Based on the 2018 China Longitudinal Aging Social Survey and the propensity score matching method to measure the impact of community home elderly care services on the four types of social participation of chronically ill elderly, including economic participation, family participation, voluntary participation, and political participation, and group differences, and uses the multiple mediation analysis method to explore the mechanism and effect of community home elderly care services on the four types of social participation of chronically ill elderly.

Results: (1) Community home elderly care services have an asymmetric impact on the social participation of the chronically ill elderly, and have generally promoted the level of social participation of the chronically ill elderly. (2) Community home elderly care services change the social participation arrangements of the chronically ill elderly by driving and inhibiting effects, so that it has a tendency to reduce economic participation and increase voluntary participation and political participation as a whole. This feature shows group differences among the chronically ill elderly of different ages, education levels, living arrangements and community types. (3) Community home elderly care services have an asymmetric impact on various social participation of the chronically ill elderly through the multidimensional health mediation mechanism.

Conclusion: (1) With the continuous deepening of the interweaving between the growth of chronic diseases and the aging of the population in China, the development of a positive aging society must attach great importance

to the important role of social participation for the chronically ill elderly. (2) Strengthen the development of physical, psychological, and social adaptation and other health abilities of the chronically ill elderly, shape their awareness of social participation, and give the chronically ill elderly a reasonable social role orientation. (3) Through policy incentives, promote the realization of fairness, justice, adequacy, and sustainability of community home elderly care services. (4) Pay special attention to the penetration, integration, and application of digital technology into the field of community home elderly care services to effectively protect the health of chronically ill elderly, ensure that the elderly with different chronic diseases participate in social activities of high quality, enjoy a high-quality happy life, and promote the high-quality development of the aging society.

1. Introduction

According to the data of the 7th National Census, there are 19.064 million people aged 65 and older in China, which accounts for 13.5% of China's total population. It is expected that in 2025 China will have 300 million people over the age of 60, and by mid-century the number will be close to 500 million, accounting for 35% of China's total population, making China a super-aged country under heavy pressure from deep aging. It is worrying that about 76.3% of the elderly in China suffer from chronic diseases, which seriously impair their ability to take care of themselves (1). Because chronic diseases have the characteristics of hidden onset, long course, high cost, and difficulty to cure, they not only damage the health level of the elderly but also greatly increase the pressure of life care and professional medical care for the elderly and reduce their willingness to participate in society. To this end, the whole society has widely gathered the consensus of "active and healthy aging" and believes that Chinese society should continue to establish and improve the elderly care service system "based on home, supported by community, supplemented by institutions, and combined with medical care," promote "the integrated development of home, community, and institutional elderly care," promote "the coordination of home, community, and institutions, and the combination of medical and health care," and community home elderly care services will become a way to achieve the health of all the elderly. It is an important practical way for the whole population to participate and ensure coordinated development in an all-round way (2–4). Therefore, how does the community home elderly care services directly affect the social participation of the chronically ill elderly? How does the community home elderly care services affect the social participation of the chronically ill elderly through multi-dimensional health mediation? This requires a systematic, theoretical answer. For this reason, based on the data of the 2018 China Longitudinal Aging Social Survey, this paper builds a matching regression model for the score of community home elderly care services and a multi-dimensional health mediation model for community home elderly care services and discusses the relationship between

"community home elderly care services" and "social participation of the chronically ill elderly."

2. Literature review

2.1. Research on community home elderly care services for the chronically ill elderly

With the extension of life span, the incidence rate of chronic diseases in the elderly is getting higher and higher, which requires long-term and sustainable medical services and health management. The separation of medical care and nursing care can not meet the health needs of the elderly. Community home elderly care services have become the focus of the development of China's elderly care service industry. Integrate medical and health resources and endowment service resources, and provide continuous and integrated services such as hospitalization, rehabilitation care, and stable life care for the chronically ill elderly through convenient and professional services (5). For older adults with chronic conditions, family physician services and appropriate medical care services, such as home care and day care, can be provided to older adults, or medical services can be provided through community-based primary care (6). As a kind of integrated care, community home elderly care services integration is a new model of elderly care service worth advocating in China, which is centered on the community, bridging the elderly service centers and health service departments in the community, and integrating rehabilitation and nursing services in the community into an integrated management platform, meeting the wishes of the chronically ill elderly to age at home while taking into account the needs of the chronically ill elderly to age healthily.

2.2. Research on the connotation and influencing factors of social participation

Ernest W. Burgess, an American scholar, was the first to introduce the concept of social participation to the elderly

population, highlighting the social values that older people have (7). The definition of social participation mainly focuses on the exchange of resources, social relations, and broader social activities. It emphasizes that in the process of social participation, people can contact and interact with others to gain individual value. From the perspective of resource exchange, Bukov et al. (8) believe that social participation is socially oriented individual resource sharing, which can be divided into three types: collective participation, productive participation, and political participation. Levesseur et al. have studied the leisure activities, participation in community activities, and volunteer activities of the elderly (9). Alma et al. (10)has included economic, political, cultural, and other activities in the social participation of the elderly, mainly including economic participation, family participation, voluntary participation, and political participation. Horman and Kiak summarized several decades of relevant research on social participation and finally concluded that the social participation of the elderly is to participate in social activities and interact with people in society and communities (11). Van Hees et al. (12) defined the social participation of older adults as older adults participating in social and productive activities that benefit themselves and society. Secondly, the social participation of the elderly is affected by many factors. Individual characteristics of the elderly, such as age, gender, education, health, marriage, cognitive ability, occupation, social status, political status, economic status, value preference, the social participation concept, and motivation, directly affect the content, mode, and level of social participation of the elderly (13).

2.3. Research on health mediation mechanism

Scholars have proposed that care services are conducive to improving the quality of life of the elderly, thus affecting their mental and physical health. When the quality of life of the elderly is low, their physical and mental health will significantly decline, causing significant depression, loneliness, and physical pain (14). Lenardt et al. (15) believed that home-based care can reduce the depression, loneliness, and physical pain of the elderly through regular visits, systematic intervention, and evaluation of the elderly. Zhu et al. (16) proposed the collaboration of community-based elderly institutions and the medical and health care consortium to support the elderly's healthy living abilities at home, allowing the chronically ill elderly to maintain and improve their physical, psychological, and social health. Some scholars also pointed out that care services have a negative impact on the physical and mental health of the elderly. The external stimulation of the elderly receiving services at home will further weaken them, increase their sense of loneliness and isolation, and then present a more inactive state (17). The impact of community home elderly care services on the health of the elderly is determined by the service's quality. When the quality of service meets the needs of the elderly, the physical pain, loneliness, and isolation of the elderly will be weakened, while the service does not meet their own needs, which will cause a series of negative problems such as ADL dysfunction, depression, physical pain perception, life pressure perception, etc. (18). In general, although scholars have different views on the impact of care services on the health of the elderly, they generally agree that community home elderly care services have a significant impact on the health of the elderly. From the perspective of active aging, the social health of the elderly is as important as their mental and physical health. To explore the health of chronically ill elderly, we need to start from multiple dimensions and perspectives, including physical health, mental health, and social health. Secondly, the impact of health status on the social participation of the elderly is particularly concerning: first, physical health, including age and gender. For example, Japanese scholars surveyed 22,845 elderly people's daily instrumental activities and social participation in Nara and other places, and the results confirmed that the daily instrumental activities and social participation of the elderly have a significant correlation and are significantly affected by physical health; South Korean scholars investigated the social participation of 1,346 poor elderly people in South Korea. The results showed that social participation was significantly affected by physical health conditions such as age. The second type of factor is psychological. The significant correlation between mental health and social participation has been confirmed by many studies, especially among older adults, who are at high risk for mental health problems. Depression reduces the likelihood of older adults participating in social or recreational activities (19), seriously affecting their normal lives. Thirdly, social adaptation, i.e., social health, can be seen as the harmony achieved by the interaction between the elderly individual and the social environment and through the elderly's own regulation. The ability of the elderly themselves to adapt socially, i.e., the degree of social health, varies, which affects the process of social participation for the elderly (20).

To sum up, existing studies have discussed the connotation, mode, and determinants of social participation of the elderly in depth and analyzed the impact of health care services on the health of the elderly and the impact of health factors on social participation of the elderly, but the existing literature still has the following deficiencies: research on the impact of multi-focus services on the health of the elderly and the impact of the health of the elderly on social participation. However, it did not further focus on the impact of community home elderly care services on the social participation of the chronically ill elderly, nor did it focus on analyzing whether the community home elderly care services affect the social participation of the chronically ill elderly through multiple health intermediaries. The mediation effect of community home elderly care services and health factors on the social participation of the chronically ill elderly need to be further deepened, expanded, and refined. This paper uses the data of the 2018 China Longitudinal Aging Social Survey and the propensity score matching method to measure the impact of community home elderly care services on the four types of social participation of the chronically ill elderly, including economic participation, family participation, voluntary participation, and political participation, and group differences, and uses the multiple mediation analysis method to explore the mediation effect of community home elderly care services on the four types of social participation of chronically ill elderly.
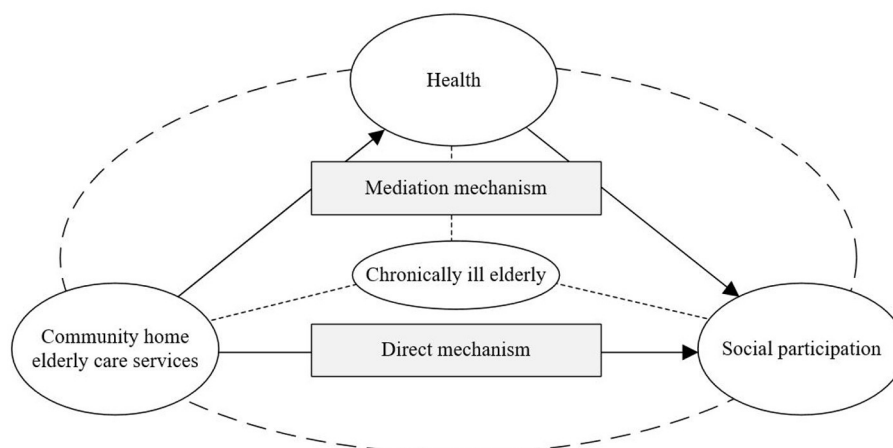
FIGURE 1
Analysis framework: influence mechanisms between community home elderly care services, health status, and social participation of chronically ill elderly.

3. Research hypothesis

According to the framework of active aging proposed by the World Health Organization, "health" is the basis of active aging, "participation" is the focus of active aging, and "security" is the necessary condition for the "health" and "participation" of the elderly. The three are organically integrated. From the perspective of participation, the social role theory points out that the social participation of individuals is related to the objective environment or specific situation they face. In order to meet their own needs, the elderly will prioritize various forms of social participation, such as economic participation, political participation, voluntary participation, family participation, and so on, based on the conflict between multiple social role expectations and their limited abilities (21). Maslow's hierarchy of needs theory holds that individual needs are inherently composed of different levels, and the satisfaction of low-level needs is the basic premise for the emergence of high-level needs, which also become the power to encourage and guide individuals to carry out social activities. In other words, the chronically ill elderly also have priorities for various social participation. Only after meeting the most basic needs through social participation can they have the energy to consider high-level social participation. However, the chronically ill elderly are relatively weak in physical function, psychological status and social adaptation, and it is relatively difficult to carry out various social participation. For this problem, social support theory proposes to provide life care, emotional comfort and material support for vulnerable groups, which will help improve the social participation ability of the chronically ill elderly and maximize their sense of participation, sense of gain and sense of happiness. The community home elderly care services mode effectively integrates the resources of medical care and elderly care institutions, not only providing life care, but also providing professional medical care, trying to improve the social participation and quality of life of the chronically ill elderly through service guarantee. It can be seen that community home elderly care services will have an impact on the social participation of the chronically ill elderly. However, the specific

impact direction and size will vary with the specific content of social participation. At the same time, the chronically ill elderly with different age, education level, living arrangement, community type and other characteristics, after using community home elderly care services, they may make differentiated social participation arrangements because of their own social participation capacity differences or differences in various social participation needs. Therefore, the following assumptions are proposed:

H1: Community home elderly care services have an asymmetric impact on the economic participation, political participation, voluntary participation, and family participation of the chronically ill elderly, and there are group differences among the chronically ill elderly with different characteristics.

Community home elderly care services model aims at healthy aging for the whole society and aims at maintaining the functions of the elderly, promoting their social participation, bringing out their values, and improving their wellbeing, thus enhance the health of the elderly (22). Health status in turn affects the level of social participation of older adults. The physical health status of chronically ill elderly adults is the primary factor limiting their social participation. In addition to being related to physical health, social participation is also related to mental health and other factors. Psychological factors such as emotions can affect a person's ability to be active. Excessive stress or extreme depression can cause mood swings that affect their activities, such as a reluctance to approach people when sad, depressed, or bored and reduced social participation. Social health, on the other hand, refers to the individual's active interaction with social relationships in social roles and the various feelings of gain and identity gained from social activities. Unlike physical and mental health, social health is more interactive, and a person with a high level of social health should be actively involved in social activities. However, the processes and mechanisms by which community home elderly care services affect the social participation of chronically ill elderly people through their health status are currently unclear. However, considering the

asymmetric impact of community home elderly care services on the health of the elderly and the asymmetric impact of health on the social participation of the elderly, it can be theoretically concluded that the mediation role of community home elderly care services in influencing the social participation of the chronically ill elderly through physical health, mental health, and social health is asymmetric. Therefore, the following hypothesis is proposed:

H2: Community home elderly care services influence social participation asymmetrically through the mediating effects of physical health, mental health, and social health.

Based on the research hypothesis, this paper constructs a mechanism analysis framework for exploring community-based home health care services, multidimensional health, and social participation of the chronically ill elderly, as shown in Figure 1.

4. Research design

4.1. Data sources

The data in this article is based on the 2018 China Longitudinal Aging Social Survey (CLASS). The survey adopted a multi-level and multi-stage probability sampling method. Eleven thousand four hundred nineteen samples were collected from 462 villages (residents) in 28 provinces, autonomous regions, and municipalities (except Hainan, Xinjiang, Tibet, Hong Kong, Macao, and Taiwan), covering information about the health, social participation, and community environment of the elderly aged 60 and above. As this paper focuses on the chronically ill elderly, a sample of chronically ill elderly was analyzed. After variable screening and missing value processing, 5,555 valid samples were finally obtained.

4.2. Variable description

4.2.1. Dependent variable

This paper's dependent variable is social participation. The types and contents of social participation are very rich. Based on the literature, this paper measures the social participation of the chronically ill elderly in four dimensions: economic participation, family participation, voluntary participation, and political participation (23, 24).

First, economic participation is a binary variable set to "participation = 1, non-participation = 0" in the questionnaire item "Current Situation of Your Work/Activity with Income."

Second, family participation is set as a binary variable of "participation = 1, non-participation = 0" according to parental care, household help, and intergenerational care of the chronically ill elderly. The term "parental care" is derived from the question, "Do your own (or your spouse's) parents still require care?" Household help comes from the question, "How often have you helped this child do housework in the past 12 months?" The intergenerational care is derived from the question item, "The time you spent taking care of your first child in the past 12 months."

Third, according to the questionnaire item, "How often have you participated in the following activities in the past year?" Set as a binary variable of "participation = 1, non-participation = 0." These voluntary activities include community security patrols, caring for other elderly or children, environmental health protection, neighborhood dispute mediation, accompanying chats, voluntary services, caring for and educating the next generation, etc.

Fourth, political participation is based on the questionnaire item, "Have you participated in the voting of the local residents' committee or villagers' committee in the past 3 years?" Generate a binary variable of "participation = 1, non-participation = 0." Table 1 shows that the social participation rates of the chronically ill elderly in economy, family, volunteering, and politics are 22.7%, 54.3%, 31.4%, and 40.9%, respectively.

4.2.2. Independent variable

The independent variable of this article is the community home elderly care services. This variable is based on whether the respondents in the questionnaire have used such items as "home visit, home care, home visit, home housework, elderly service hotline, accompanying doctor, helping daily shopping, legal aid, elderly dining table or delivery, day care station or nursing home, psychological consultation, rehabilitation training, rental of rehabilitation aids, free physical examination, establishment of health files, health lectures," a binary variable set to "any service used = 1, no service used = 0 (25)." Table 1 shows that in 2018, about 39% of the chronically ill elderly were covered by community home elderly care services in China.

4.2.3. Mechanism variables

According to the literature and research assumptions, this paper focuses on the impact of community home elderly care services on the social participation of the chronically ill elderly through the three mechanism variables of physical health, mental health, and social health (26).

First, the physical health was measured objectively by the "Activity of Daily Living (ADL)" scale consisting of 12 items in the questionnaire, which include the basic activity of daily living (BADL) and instrumental activity of daily living (IADL). Among them, BADL includes dressing, bathing, eating, defecation control, toileting, indoor action, and other items, while IADL includes bus travel, shopping, money management, lifting 10 kg, cooking, housework, and other items. In this paper, the answer items "don't need help from others," "need some help," and "can't do it at all" are assigned three points, two points, and one point, respectively, and the answer items "can" and "can't" are assigned two points and one point, respectively, and the continuous variable between 12 and 34 is obtained by summing up. The higher the value, the better the physical health. The Cronbach's alpha reliability coefficient test of the sample is 0.897, indicating that the scale has high reliability.

Secondly, mental health was investigated according to the "Depression" scale, consisting of 12 items in the questionnaire that reflected the respondents' psychological states of "mood, loneliness, sadness, life satisfaction, diet, sleep, interest, companionship, feelings of not being useful, feelings of having nothing to do, feelings of being ignored, and feelings of being isolated."

TABLE 1 Descriptive statistics of variables.

Variable		Variable type	Assignment description	Full sample		Treatment group		Control group	
				Mean value	SD	Mean value	SD	Mean value	SD
Dependent variable									
Economic participation		Dummy	Participation = 1, non-participation = 0	0.227	0.419	0.188	0.390	0.253	0.435
Family participation		Dummy	Participation = 1, non-participation = 0	0.543	0.498	0.539	0.499	0.546	0.498
Voluntary participation		Dummy	Participation = 1, non-participation = 0	0.314	0.464	0.350	0.477	0.290	0.454
Political participation		Dummy	Participation = 1, non-participation = 0	0.409	0.492	0.446	0.497	0.385	0.487
Independent variable									
Community home elderly care services		Dummy	Have used any community home elderly care services, the answer is 1, otherwise it is 0	0.393	0.488	\	\	\	\
Mechanism variable									
Physical health		Category	Score between 12–34	33.059	2.456	32.835	2.879	33.205	2.125
Mental health		Continuous	Score between 12–36	27.647	4.107	27.982	4.081	27.430	4.110
Social health		Continuous	Score between 8–24	16.421	3.104	16.619	3.815	16.307	3.178
Control variable									
Personal characteristics	Age	Continuous	Calculated according to the date of birth	71.434	7.189	71.996	7.448	71.070	6.993
	Gender	Dummy	Male = 1, female = 0	0.497	0.500	0.477	0.500	0.510	0.500
	Registered residence	Dummy	Non-agricultural household registration = 1, otherwise = 0	0.516	0.500	0.561	0.496	0.488	0.500
	Education level	Category	Below primary school = 0, primary school = 1, junior high school = 2, senior high school and above = 3	1.212	0.974	1.161	0.966	1.245	0.978
	Digital literacy	Dummy	Being able to engage in chatting, shopping, browsing information, entertainment, transportation, health management, investment and financing, and learning and training through a digital network = 1, otherwise = 0	0.214	0.410	0.217	0.412	0.213	0.409
	Major event experience	Dummy	Whether you have experienced important events in the past 12 months	0.282	0.450	0.333	0.471	0.249	0.432
	Smoking	Dummy	Still smoking = 1, no longer smoking = 0, never smoked = 0	0.215	0.411	0.222	0.416	0.210	0.407
	Number of chronic diseases	Continuous	According to the number of chronic diseases	11.221	7.613	11.148	7.635	11.268	7.599
Family characteristics	Marriage	Dummy	Married = 1, widowed, divorced, unmarried = 0	0.683	0.465	0.669	0.471	0.692	0.462
	Living alone	Dummy	Living alone = 1, otherwise = 0	0.878	0.328	0.871	0.335	0.882	0.323
	Number of children	Dummy	Number of living children	2.505	1.344	2.386	1.323	2.581	1.353
	Family income	Continuous	Logarithm of per capita household income	8.147	1.401	8.289	1.369	8.055	1.414
Social characteristics	Endowment insurance	Dummy	Have enjoyed the basic endowment insurance of enterprise employees, government institutions and urban and rural residents = 1, otherwise = 0	0.801	0.399	0.885	0.319	0.746	0.435
	Type of residential community	Dummy	Living in rural community = 1, otherwise = 0	0.398	0.489	0.360	0.480	0.422	0.494
Sample size				5,555		2,180		3,375	

FIGURE 2
Nuclear density distribution of propensity scores of treatment group and control group before and after matching.
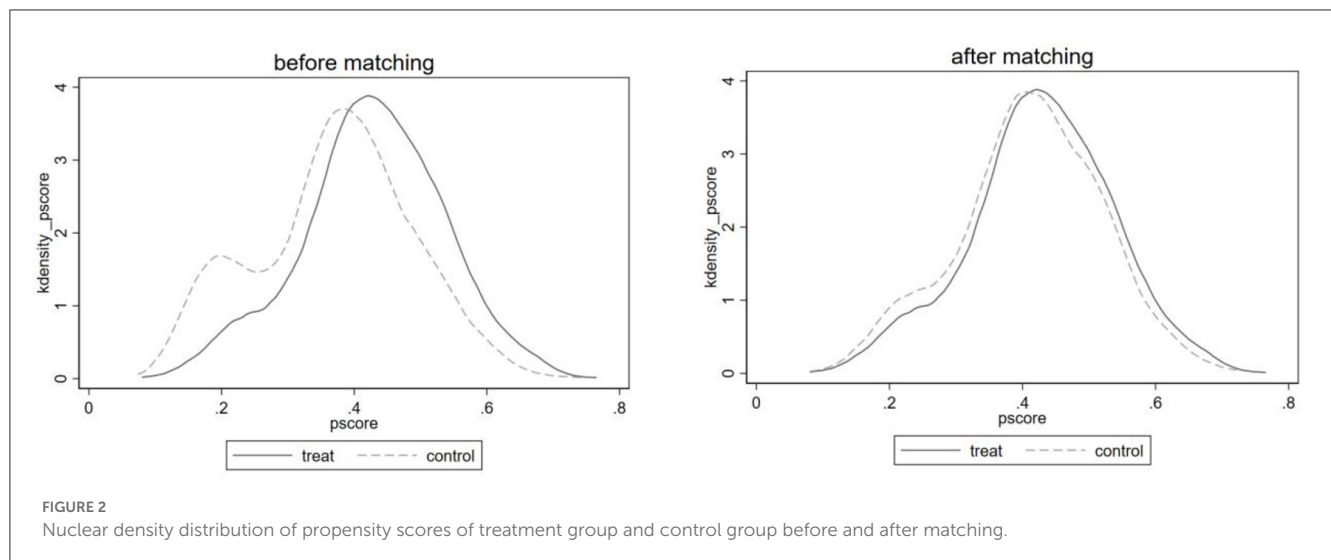
The answers of "no," "sometimes," and "often" were assigned one point, two points, and three points, respectively, and the negative items were summed up after being processed in reverse order, A continuous variable between 12 and 36 is obtained. The higher the value, the lower the depression and mental health of the chronically ill elderly. The Cronbach's reliability coefficient is 0.758, which indicates that the reliability of the scale is high.

Third, social health was investigated according to the eight items in the questionnaire that reflected the respondents' "enthuasia for work participation, social dedication, love for learning, self-social value perception, social change adaptation, acceptance of social concepts, acceptance of social policies, and awareness of social friendliness." The answers "completely inconsistent" and "relatively inconsistent" were assigned one point each, "general" was assigned two points, the values of "relatively consistent" and "completely consistent" were assigned three points, and the negative items were processed in reverse order and summed up to obtain continuous variables with values between 8 and 24. The higher the score, the better the social health. The Cronbach's alpha reliability coefficient is 0.826, which meets the data quality requirements.

4.2.4. Control variables

According to the existing literature, this paper controls the individual, family, and social characteristics of the chronically ill elderly to reduce the research bias caused by the omission of variables (27, 28). Among them, individual characteristics include age, gender, registered residence, education level, digital literacy, major events experience, smoking, and number of chronic diseases; family characteristics include marriage, living alone, number of children, and family income; social characteristics include variables such as endowment insurance and type of residential community.

The specific variable meaning, assignment, and descriptive analysis results are shown in Table 1.

4.3. Research methods

4.3.1. Propensity score matching

In the study of inferring the actual causal relationship between two variables, selective bias and mixed bias often seriously interfere with the estimation results. The ideal test is to adopt the random test method of completely controlling the characteristic variables (29). Therefore, the best method in this study is to reveal the impact of community home elderly care services on the social participation of the chronically ill elderly by comparing the difference in social participation between the treatment group (the chronically ill elderly who use community home elderly care services) and those who do not receive community home elderly care services. However, in reality, it is impossible to observe whether the social participation of the treatment group will change without using community home elderly care services, because this is a "counterfactual." To solve this problem, Rosenbaum and Rubin (30) proposed a counterfactual inference model of the propensity score matching method (PSM). Its basic idea is to build a counterfactual framework that can approximate randomizing non-random data by finding counterfactual control groups similar to the processing group while simultaneously reducing the dimension of multiple observable characteristic variables to match, so as to eliminate sample bias to the maximum extent and ensure more accurate estimation results. The specific ideas are as follows:

The first step is to use the Logistic model to estimate the tendency score of the chronically ill elderly to use community home elderly care services:

$$Logit(Service_i = 1) = \alpha + \beta X_i + e_i \qquad (1)$$

Among them, $Service_i$ is the community home elderly care services, and X_i is the vector composed of personal, family, and social characteristic variables.

The second step is to find comparable objects with similar propensity scores for each treatment group sample in the control group for pair analysis and ensure effective matching by jointly supporting the hypothesis test and balance test. At present, the

TABLE 2 Balance test results.

Variable	Logit Model	Matching status	Mean		Mean difference test	
			Treated	Control	Bias (%)	T-test p > |t|
Age	0.026***	Unmatched	72.006	71.070	13.0	0.000
	(0.005)	Matched	71.990	72.038	−0.7	0.829
Gender	−0.142**	Unmatched	0.477	0.510	−6.6	0.016
	(0.064)	Matched	0.477	0.501	−4.7	0.122
Registered residence	0.047	Unmatched	0.561	0.488	14.7	0.000
	(0.095)	Matched	0.561	0.554	1.3	0.669
Education level	−0.212***	Unmatched	1.162	1.245	−8.5	0.002
	(0.036)	Matched	1.163	1.202	−4.0	0.188
Digital literacy	0.023	Unmatched	0.217	0.213	0.9	0.738
	(0.080)	Matched	0.217	0.219	−0.7	0.826
Major event experience	0.432***	Unmatched	0.333	0.249	18.6	0.000
	(0.063)	Matched	0.332	0.348	−3.5	0.277
Smoking	0.157**	Unmatched	0.222	0.210	2.9	0.290
	(0.075)	Matched	0.222	0.226	−1.0	0.744
Number of chronic diseases	−0.007*	Unmatched	11.148	11.268	−1.6	0.567
	(0.004)	Matched	11.147	11.003	1.9	0.528
Marriage	0.053	Unmatched	0.669	0.692	−5.0	0.068
	(0.075)	Matched	0.669	0.667	0.8	0.797
Living alone	−0.103	Unmatched	0.871	0.882	−3.2	0.236
	(0.101)	Matched	0.872	0.862	2.9	0.349
Number of children	−0.175***	Unmatched	2.386	2.581	−14.6	0.000
	(0.025)	Matched	2.388	2.392	−0.3	0.925
Family income	0.080***	Unmatched	8.289	8.055	16.7	0.000
	(0.025)	Matched	8.289	8.301	−0.9	0.780
Endowment insurance	0.950***	Unmatched	0.885	0.746	36.3	0.000
	(0.083)	Matched	0.885	0.887	−0.5	0.849
Type of residential community	0.070	Unmatched	0.360	0.422	−12.6	0.000
	(0.094)	Matched	0.360	0.350	2.1	0.486

***p < 0.01, **p < 0.05, *p < 0.1, respectively indicate that the estimated results are significant at 1%, 5%, and 10% levels. The parentheses are standard errors.

academic community has not reached a consensus on the selection of specific matching methods. In this paper, the nearest neighbor matching method is selected first, and other matching methods are replaced in the robustness test.

The third step is to estimate the average treatment effect for the treated (ATT) of the treatment group according to the matched samples:

$$ATT = E\{E[Y_{1i} - Y_{0i}|D_i = 1]\} = E\{E[Y_{1i}|D_i = 1] - E[Y_{0i}|D_i = 0]\} \ (2)$$

Among them, Y_{1i} and Y_{0i} represent the social participation indicators of the chronically ill elderly who use and do not use community home elderly care services respectively; D_i is a key independent variable, indicating whether the chronically ill elderly

use community home elderly care services. If they have, $D_i = 1$; otherwise, $D_i = 0$.

4.3.2. Multiple mediation analysis

Since the introduction of the causality stepwise regression test by Baron and Kenny (31), the mediation analysis method has evolved rapidly and gradually from simple mediation analysis of a single mediation variable to multiple mediation analysis of multiple mediation variables. At the same time, more attention has been paid to clarifying the three mechanisms of mediation effect, confounding effect, and suppressing effect in mediation analysis. Both mediation effect variables and confounding effect variables can reduce the total effect of independent variables on dependent variables. The difference is that mediation effect variables are in

TABLE 3 Average treatment effect for the treated of different matching methods.

Matching method	Economic participation		Family participation		Voluntary participation		Political participation	
	ATT	T-value	ATT	T-value	ATT	T-value	ATT	T-value
K-nearest neighbor matching(K=1)	−0.036** (0.016)	−2.25	0.024 (0.019)	1.22	0.046* (0.018)	2.56	0.079** (0.019)	4.17
Radius matching (0.001)	−0.031** (0.012)	−2.53	0.014 (0.015)	0.96	0.050*** (0.014)	3.56	0.069*** (0.015)	4.066
Nuclear matching	−0.027** (0.012)	−2.34	0.005 (0.014)	0.32	0.043*** (0.013)	3.20	0.058*** (0.014)	4.07
Markov matching	−0.032** (0.011)	−3.01	−0.009 (0.015)	−0.59	0.056*** (0.014)	4.08	0.059*** (0.015)	4.300
ATT average	−0.032		0.009		0.049		0.067	

***p < 0.01, **p < 0.05, *p < 0.1, respectively indicate that the estimated results are significant at 1%, 5%, and 10% levels. The parentheses are standard errors.

the causal chain between independent variables and dependent variables, while confounding effect variables are not necessarily in the causal relationship between them; the suppressing effect will increase the total effect of independent variables on dependent variables (32). This paper intends to use multiple mediation analysis to reveal the mechanism of community home elderly care services affecting the social participation of the chronically ill elderly through three mediation variables: physical health, mental health, and social health. The relationship function between the main variables in the multiple mediation analysis is:

$$Y_{ip} = \beta_0^1 + \beta_j^1 Service_{ij} + \sum_{l=1}^{n} \beta_l^1 X_{il} + \varepsilon_i^1 \quad (3)$$

$$Health_{ik} = \beta_0^2 + \beta_j^2 Service_{ij} + \sum_{l=1}^{n} \beta_l^2 X_{il} + \varepsilon_i^2 \quad (4)$$

$$Y_{ip} = \beta_0^3 + \beta_j^3 Service_{ij} + \sum_{k=1}^{3} \beta_k^3 Health_{ik} + \sum_{l=1}^{n} \beta_l^3 X_{il} + \varepsilon_i^3 \quad (5)$$

Among them, $Y_{ip}(p = 1, 2, 3, 4)$ represents the four dependent variables of economic participation, family participation, voluntary participation, and political participation of the chronically ill elderly; $Health_{ik}(k = 1, 2, 3)$ represents the three mediation variables of physical health, mental health, and social health; and ε represents the error term. Formula (3) is used to test the direct effect of community home elderly care services on the social participation of the chronically ill elderly; Formula (4) is used to test the impact of community home elderly care services on health mediation variables; the indirect effect of mediation variables can be obtained by substituting Formula (4) for Formula (5). If coefficients β_j^2 and β_k^3 are significant, it can be determined that community home elderly care services affect the social participation of the chronically ill elderly through health mediation variables.

5. Empirical results

This part uses the propensity score matching model to analyze the direct effects of community home elderly care services on the economic participation, family participation, voluntary participation, and political participation of the chronically ill

elderly and discusses the group differences of community home elderly care services on the social participation of the elderly with different types of chronic illnesses.

5.1. Propensity score matching quality analysis

According to formula (1) above, calculate the propensity score of the chronically ill elderly to receive community home elderly care services and use the K nearest neighbor matching ($K = 1$, caliper = 0.05) method to match the propensity scores of various characteristics of the treatment group and the control group, and then test the common support hypothesis and balance hypothesis to ensure that the PSM estimation is effective.

First of all, the common support hypothesis requires that the trend values of the treatment group and the control group have a common range of values. As shown in Figure 2, there is a significant difference in the nuclear density distribution between the pre-matching treatment group and the control group. After matching, the trend of the nuclear density curves of the two groups of samples tends to be consistent and highly fitted, indicating that the matching effect is ideal and meets the common support hypothesis.

Secondly, the PSM balance hypothesis requires that there be no significant difference in control variables between the treatment group and the control group after sample matching (Table 2). Balance test results show that the standardized deviation of each control variable in the sample matching post-processing group and the control group is greatly reduced, and their absolute values are less than the 20% red line specified in the balance test, which indicates that the selection of matching variables is more reasonable, meets the balance assumption, and the matching quality is high, which can effectively reduce the estimation error caused by sample self-selection.

5.2. Propensity score treatment effect analysis

Table 3 reports the average treatment effect for the treated (ATT) of the use of community home elderly care services on the economic participation, family participation, voluntary

TABLE 4 Group differences in the impact of community home elderly care services on the social participation (ATT) of the chronically ill elderly.

Variable		Variable sample size	Economic participation		Family participation		Voluntary participation		Political participation	
			ATT	T-value	ATT	T-value	ATT	T-value	ATT	T-value
Age	60–69 years old	2662	0.004 (0.025)	0.16	−0.009 (0.026)	−0.33	0.059** (0.026)	2.23	0.089*** (0.028)	3.17
	70–79 years old	2017	−0.029 (0.025)	−1.19	0.017 (0.033)	0.55	0.045 (0.030)	1.49	0.083*** (0.032)	2.64
	80 years old and above	876	−0.104*** (0.034)	−3.12	−0.078* (0.047)	−1.65	−0.002 (0.043)	−0.06	0.077* (0.044)	1.74
Education level	Primary school and below,	3521	−0.037* (0.022)	−1.72	−0.005 (0.025)	−0.20	0.112*** (0.021)	5.28	0.020 (0.025)	0.08
	Junior high school	1377	−0.035 (0.028)	−1.28	−0.015 (0.037)	−0.42	−0.049* (0.037)	−1.33	0.142*** (0.037)	3.86
	High school and above	657	0.026 (0.035)	0.74	−0.065 (0.057)	−0.11	0.116** (0.058)	2.00	0.142* (0.057)	2.49
Residential arrangement	Living alone	680	−0.028* (0.017)	−1.65	0.010 (0.020)	0.49	0.027** (0.019)	1.44	0.073*** (0.019)	3.67
	No living alone	4875	−0.004 (0.045)	−0.08	−0.022 (0.052)	−0.42	0.115** (0.051)	2.27	0.093* (0.053)	1.76
Community-type	Non-agricultural community	3347	−0.004 (0.012)	−0.36	0.017 (0.024)	0.70	0.043* (0.023)	1.84	0.073*** (0.023)	3.13
	Rural communities	2208	−0.048 (0.031)	−1.52	−0.012 (0.031)	−0.37	0.002** (0.028)	−0.07	0.045 (0.032)	1.41

***, **, and * indicate significance at 1%, 5%, and 10% levels. The parentheses are standard errors.

participation, and political participation of the chronically ill elderly under the four methods of K-nearest neighbor matching, radius matching, nuclear matching, and Markov matching, after controlling the characteristic variables. The results showed that there was no significant difference between the ATT and t values obtained by the four matching methods, indicating that the influence of community home elderly care services on the social participation of the chronically ill elderly was not interfered with by the propensity score matching method and had good robustness. The arithmetic mean value of ATT of four matching methods was selected for further analysis, and it was found that community home elderly care services had an asymmetric impact on the social participation of the chronically ill elderly. First, in terms of economic participation, the treatment group's average treatment effect was −0.032, implying that using community home elderly care services significantly reduced the economic participation rate of the chronically ill elderly by 3.2%; Second, the average treatment effect of the treatment group in terms of voluntary participation and political participation was 0.049 and 0.067, respectively, indicating that the use of community home elderly care services significantly increased the voluntary participation rate of 4.9% and the political participation rate of 6.7% of the chronically ill elderly; Finally, in terms of family participation, the evaluation and treatment effect of the treatment group is not significant, that is, the use of community home elderly care services has a neutral effect on family participation of the chronically ill elderly.

It can be seen that the use of community home elderly care services will change the social participation arrangements of the chronically ill elderly and make them show a tendency to reduce economic participation and increase voluntary participation and political participation. On the one hand, this is because community home elderly care services help improve the quality of life of the chronically ill elderly, improve the demand level of the chronically ill elderly, enhance the social participation ability of the chronically ill elderly, and ultimately reduce the economic participation of the chronically ill elderly and promote their voluntary participation and political participation. On the other hand, it can be explained that the chronically ill elderly will adjust their social role response strategies after using community home elderly care services according to their social roles and the differentiated functions of the four types of social participation and form a new balance of social participation arrangements. On the other hand, the chronically ill elderly under the Chinese "family" culture have a profound "father is kind and son is filial" blood relationship and the filial piety gene. Because of the rigid value preferences of the chronically ill elderly for filial piety, ancestor worship, inheritance, and blood continuity, community home elderly care services will find it difficult to influence family participation.

5.3. Group difference analysis

The chronically ill elderly will be affected differently by community home elderly care services due to their different age stages, education levels, residential arrangements, and community-types. Table 3 reports the average effect of community home elderly care services on the social participation of the chronically ill elderly,

TABLE 5 Multiple health mediating effects.

Impact path	Total direct effect	Mediation effect	95% BootLLCI	95% BootULCI	Proportion of mediation effect or suppressing effect value (%)
1.Community home elderly care services → physical health → economic participation	−0.268*** (0.085)	−0.051 (0.017)	−0.091	−0.021	15.5%
2.Community home elderly care services → mental health → economic participation		−0.060 (0.019)	0.006	0.029	18.3%
3.Community home elderly care services → social health → economic participation		0.015 (0.006)	−0.103	−0.025	4.6%
4.Community home elderly care services → physical health → family participation	0.059 (0.061)	−0.015 (0.006)	−0.028	−0.005	44.4%
5.Community home elderly care services → mental health → family participation		−0.003 (0.005)	−0.014	0.007	[5.1%]
6.Community home elderly care services → social health → family participation		−0.007 (0.004)	−0.016	−0.001	20.7%
7.Community home elderly care services → physical health → voluntary participation	0.278*** (0.064)	0.0002 (0.003)	−0.006	0.006	[0.1%]
8.Community home elderly care services → mental health → voluntary participation		0.043 (0.009)	0.027	0.062	13.3%
9.Community home elderly care services → social health → voluntary participation		0.019 (0.004)	−0.005	0.010	[6.8%]
10.Community home elderly care services → physical health → political participation	0.268*** (0.060)	−0.018 (0.066)	−0.033	−0.007	6.6%
11.Community home elderly care services → mental health → political participation		0.008 (0.005)	−0.002	0.019	[2.9%]
12.Community home elderly care services → social health → political participation		0.013 (0.005)	0.006	0.024	4.8%

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, respectively indicate that the estimated results are significant at 1%, 5%, and 10% levels. The parentheses are standard errors. The value in brackets is the suppressing effect value, which is calculated by dividing the suppressing effect by the direct effect (taking the absolute value). The percentage of mediation effect is the percentage of mediation effect in total effect. If the BootLLCI–BootULCL interval does not contain 0, the indirect effect is significant; the estimation results of control variables are omitted.

but it cannot reflect the structural difference in the impact effect of the chronically ill elderly, that is, group differences. This paper discusses the group differences of different types of elderly people, which will help enrich the research content of community home elderly care services on the social participation of the chronically ill elderly. The group difference results based on the nearest neighbor matching method are shown in Table 4.

5.3.1. Age group differences

With reference to the age standard of the United Nations, this paper divides the samples into three groups: the young elderly (60–69 years old), the middle-aged elderly (70–79 years old), and the elderly (80 years old and above) to explore the potential differences in the impact of community home elderly care services on the chronically ill elderly at different ages. It can be seen from Table 4 that the community home elderly care services have a significant positive impact on the voluntary participation and political participation of the young people aged 60–69, a significant negative impact on the political participation of the middle-aged people aged 70–79, a significant negative impact on the economic participation and family participation of the elderly aged 80 and above, and a significant positive impact on their political participation.

5.3.2. Educational group differences

According to the education level of the chronically ill elderly, this paper is divided into three groups: primary school and below, junior high school, senior high school and above. It can be seen from Table 4 that the community home elderly care services have a significant negative impact on the economic participation of the chronically ill elderly at primary school and below and a significant positive impact on voluntary participation; the community home elderly care services have a significant negative impact on the voluntary participation of the chronically ill elderly at junior high school level and a significant positive impact on political participation; and the community home elderly care services have a significant positive impact on the voluntary participation and political participation of the chronically ill elderly at high school and above.

5.3.3. Residential arrangement group differences

According to the residential arrangements of the chronically ill elderly, this paper divides them into two groups: solitary and non-solitary. It can be seen from Table 4 that the community home elderly care services have a significant positive effect on the voluntary participation and political participation of the chronically ill elderly living alone and not living alone, but the

effect on the chronically ill elderly not living alone is greater than that of the chronically ill elderly living alone. In addition, community home elderly care services have a significant negative impact on the economic participation of the elderly living alone with chronic diseases.

5.3.4. Community-type group differences

For analysis, this paper divides the types of residential communities for the chronically ill elderly into two groups: non-agricultural communities and rural communities. It can be seen from Table 4 that the community home elderly care services have a significant positive impact on the voluntary participation and economic participation of the chronically ill elderly living in non-agricultural communities, but only has a significant positive impact on the voluntary participation of the chronically ill elderly in rural communities.

6. Mechanism analysis

The above research focuses on how community home elderly care services can affect the social participation of the chronically ill elderly. In order to further clarify how community home elderly care services affect the social participation of the chronically ill elderly, this paper uses the bias-corrected non-parametric Bootstrap method to conduct a multiple mediation analysis of 5,000 repeated samples to test the mechanism by which the community home elderly care services affect the social participation of the chronically ill elderly.

Table 5 shows that in the path of community home elderly care services affecting the economic participation of the chronically ill elderly, the total direct effect is significantly negative at the 1% statistical level, the mediation effects of physical health and mental health are significantly negative, and the mediation effect of social health is significantly positive, indicating that physical health, mental health, and social health play a "partial mediation effect." In other words, community home elderly care services not only have a direct negative impact on the economic participation of the chronically ill elderly but also inhibit the economic participation of the chronically ill elderly through the negative "mediation effect" of physical health and mental health, which account for 15.5 and 18.3% of the total effect, respectively, and also promote the economic participation of the chronically ill elderly through the positive "mediation effect" of social health, which accounts for 4.6% of the total effect.

In the path of community home elderly care services affecting the family participation of the chronically ill elderly, the total direct effect is positive but not significant, the mediation effect of physical health and social health is significantly negative, and the mediation effect of mental health is not significant, indicating that the community home elderly care services inhibit the family participation of the chronically ill elderly through the negative "complete mediation effect" of physical health and social health, which account for 44.4 and 20.7% of the total effect, respectively. Mental health has a "suppressing effect."

In the path of community home elderly care services affecting the voluntary participation of the chronically ill elderly, the total

direct effect is significantly positive at the 1% statistical level, the mediation effect of mental health is significantly positive, and the mediation effect of physical health and social health is not significant, indicating that community home elderly care services promote the political participation of the chronically ill elderly through the positive "partial mediation effect" of mental health, which accounts for 13.3% of the total effect. Physical and social health both have a "suppressing effect."

The total direct effect of community home elderly care services influencing the political participation of the chronically ill elderly is significantly positive at the 1% statistical level; the indirect effect of physical health is significantly positive; the indirect effect of social health is significantly negative; and the indirect effect of mental health is not significant, indicating that the community home elderly care services affect the political participation of the chronically ill elderly through the positive "partial mediation effect" of physical health and the negative "partial mediation effect" of social health, which account for 6.6 and 4.8% of the total effect, respectively. Mental health has a "suppressing effect."

Based on the above results, it can be seen that community home elderly care services affect the social participation of the chronically ill elderly through the asymmetry of direct mechanisms and mediation mechanisms. In terms of direct mechanisms, community home elderly care services negatively drive economic participation and positively drive voluntary participation and political participation. In terms of mediation mechanisms, community home elderly care services negatively affect economic participation, family participation, and political participation through the physical health mediation mechanism, negatively affect economic participation and positively drive voluntary participation through the psychological health mediation mechanism, and positively drive economic participation and political participation and negatively drive family participation through the social health mediation mechanism. Hypotheses 1 and 2 are verified.

7. Conclusion and discussion

Research findings: (1) The community home elderly care services have an asymmetric impact on the social participation of the chronically ill elderly. It has significantly reduced the economic participation rate of the chronically ill elderly by 3.2%, significantly increased the voluntary participation rate of the chronically ill elderly by 5.6%, and increased the political participation rate by 5.9%, but has not significantly affected the family participation of the chronically ill elderly. It has generally promoted the social participation of the chronically ill and elderly. (2) At the same time, community home elderly care services change the social participation arrangements of the chronically ill elderly by driving and inhibiting effects, so that they have a tendency to reduce economic participation and increase voluntary participation and political participation as a whole. This feature shows group differences among the chronically ill elderly of different ages, education levels, living arrangements, and community types. (3) Community home elderly care services have an asymmetric impact on various social participations of the chronically ill elderly through the

multidimensional health mediation mechanism: a negative impact on economic participation, family participation, and political participation through the physical health mediation mechanism; a negative impact on economic participation and a positive drive on voluntary participation through the psychological health mediation mechanism; a positive drive on economic participation and political participation and a negative drive on family participation through the social health mediation mechanism.

Among the three pillars of "health," "participation," and "security," the framework of active aging emphasizes the importance of "participation," emphasizes that it is based on security and supported by health, and encourages the elderly to actively engage in social participation activities. The chronically ill elderly are vulnerable groups with poor physical function, mental state, and social adaptability. Their basic ability to reasonably arrange social participation in the face of social role conflict is lower, and their social participation still has a large room for adjustment in realizing their old age and meeting social expectations (33). At this time, it is necessary to carry out security interventions for the chronically ill elderly (34). This study shows that at present, the social participation of the chronically ill elderly in China shows the basic characteristics of "family participation dominating, followed by political participation and voluntary participation, and economic participation being the least." However, the community home elderly care services obviously adjust the social participation arrangements of the chronically ill elderly, reduce their economic participation, and increase their social participation in voluntary and political fields, while family participation has not changed significantly. In the dimension of economic participation, the human capital, motivation for participation, and employment opportunities of the elderly are the main factors that determine their income activities (35). The chronically ill elderly have poor physical function, psychological status, and social adaptability, and the level of human capital is relatively low, so the competitiveness of economic participation is relatively weak, making their employment level often low. In particular, as a security model focusing on family and community fields to provide health care services for the elderly, the community home elderly care services may, on the one hand, weaken their motivation for economic participation by alleviating the life pressure of the chronically ill elderly and improving their quality of life, and, on the other hand, lock the social space of the chronically ill elderly in the scope of family and community, thus reducing their chances of obtaining employment, so as to further compress their employment space and ultimately reduce the economic participation rate of the chronically ill elderly. In terms of family participation, the chronically ill elderly have the highest level, and it is not significantly affected by the community home elderly care services, indicating that the social participation of the chronically ill elderly in China has a "home-based" role feature (36), that is, participation in family affairs is a rigid demand for the chronically ill elderly and is not easily met. From the perspective of voluntary participation and political participation, according to Maslow's hierarchy of needs theory, voluntary participation and political participation belong to social participation activities at a higher level of needs, which are often based on the basic

premise that the survival and safety needs can be met. Therefore, the chronically ill elderly who use the community home elderly care services can reduce their worries and pressure on their own health care so as to devote more energy to voluntary and political activities.

When the chronically ill elderly are impacted by community home elderly care services, they will make differentiated social participation arrangements due to differences in their characteristics such as age, education, living arrangements, and community type constraints, resulting in group heterogeneity. This study finds that, with the increase in age, the influence of community home medical care services on the social participation of the elderly with chronic diseases will be differentiated due to the differences in age, education level, living arrangement, community type constraints, and other characteristics, resulting in group heterogeneity, which will gradually change from increasing voluntary participation and political participation to decreasing economic participation and family participation. This is because the phical function, psychological state, and social adaptability of the young elderly are at the best stage of the life cycle of the elderly. After using the community home elderly care services to meet their most basic needs for health care, there is still room to actively carry out voluntary participation and political participation at a higher level of demand. Therefore, the community home elderly care services mainly play a driving role in the social participation of the chronically ill elderly. For the chronically ill elderly whose abilities have degenerated in all aspects, the community home elderly care services are to play a convergent role in social participation. The chronically ill elderly mainly take the strategic approach of reducing economic participation and family participation. With the improvement of the education level of the chronically ill elderly, the impact of community home elderly care services on social participation has gradually shifted from reducing economic participation and increasing voluntary participation to increasing voluntary participation and political participation. In general, the chronically ill elderly who have a higher education level have more extensive economic and material resources or social support, so they have higher expectations of their own success and quality of life in their later years. After using community home elderly care services, they are more likely to carry out social activities such as voluntary participation and political participation with a higher demand level. In terms of home arrangement, the driving role of community home elderly care services for the voluntary participation and political participation of the chronically ill elderly who are not living alone is greater than that of the chronically ill elderly who live alone. At the same time, it also inhibits the economic participation of the chronically ill elderly who live alone. This is because the chronically ill elderly living alone are often the most vulnerable group among the elderly. Compared with the chronically ill elderly living alone, they lack support and care in life and spirit, and the quality of life is worrying. Therefore, community home elderly care services effectively make up for the lack of life care and spiritual comfort faced by the elderly living alone, so as to reduce the participation of subsistence society at the low demand level and increase the voluntary participation and political participation at the high demand level. In terms of

community types, community home elderly care services have a driving effect on the voluntary participation and economic participation of the chronically ill elderly living in non-agricultural communities, but only on the voluntary participation of the chronically ill elderly in rural communities. This is because China's community home elderly care services have taken the lead in the development of urban communities, while the development of rural communities is relatively lagging and the level of community home elderly care services are relatively low, so the role of social participation of the chronically ill elderly is weak. In general, community home elderly care services have changed the social participation arrangements of the elderly with different characteristics of chronic diseases by driving and converging at the same time.

This study found that the community home elderly care services have an asymmetric impact on various social participation of the chronically ill elderly through the multidimensional health mediation mechanism, a negative impact on economic participation, family participation, and political participation through the physical health mediation mechanism, and a negative impact on economic participation and a positive drive on voluntary participation through the physical health mediation mechanism. Through the social health mediation mechanism, it positively drives economic and political participation and negatively drives family participation. In terms of physical health, physical health is the fundamental prerequisite for all social participation. Community home elderly care services negatively affect the social participation of the chronically ill elderly through the physical health mediation mechanism. On the one hand, it may be because the development of community home elderly care services in China is still at the initial stage, especially in the field of health care services, where there are shortfalls such as low resource investment, simple service, and low service quality. Therefore, it is difficult to improve the physical health of the chronically ill elderly, and may even delay their going to formal medical institutions for treatment; On the other hand, it may also be because a series of life care services provided by community home elderly care services indirectly deprive the chronically ill elderly of the opportunity to improve their physical health through self-care, which will negatively affect their physical health and thereby reduce their level of social participation. In the aspect of mental health, community home elderly care services such as door-to-door visits, service hotlines, and psychological counseling can reduce the psychological anxiety of the chronically ill elderly by improving their mental health, thereby reducing economic participation and creating subjective and objective conditions for the chronically ill elderly to participate in community voluntary activities. In terms of social health, community home elderly care services provide opportunities for the interaction between the chronically ill elderly and the social environment and provide social adaptability support for the chronically ill elderly to carry out economic and political participation.

This paper's policy enlightenment is: (1) With the continuous deepening of the interweaving between the growth of chronic diseases and the aging of the population in China, the development of a positive aging society must attach great importance to the important role of social participation for the chronically ill elderly. (2) Given that social participation arrangements for the

chronically ill elderly face the combined effects of individual health factors, family factors, community factors, social structure factors and digital literacy factors, the process of stimulating social participation of the chronically ill elderly should not only focus on enhancing the development of their own physical, psychological and social adaptation health capabilities, but also scientifically guide the chronically ill elderly and society to combine individual factors, family factors, community factors, social structure factors and digital literacy factors, shape the awareness of social participation, reasonably assign social roles to the chronically ill elderly, and effectively balance the social responsibilities, rights and obligations of the chronically ill elderly. (3) Despite the rapid development of the community home elderly care services in China, it is still in the primary stage in general. Faced with small resource investment, simple service and low service quality, the outstanding weaknesses, how to achieve equity, fairness, sufficiency, sustainability and universal accessibility of the community home elderly care services should be the focus of the community home elderly care services policy incentives, especially the need to pay attention to the embedding of digital technology into community home elderly care services to enhance the overall capacity of China's community home elderly care services. (4) In view of the complex asymmetry of community home elderly care services affecting the social participation of the chronically ill elderly, when designing the combined menu of community home elderly care services, it is necessary to effectively grasp the organic match between the multiple health characteristics of the chronically ill elderly and the differences in social participation activities and pay special attention to the penetration, integration, and application of digital technology into the field of community home elderly care services, so as to effectively ensure the health of the chronically ill elderly, ensure that the elderly with different chronic diseases participate in social activities with high quality, enjoy a happy life with high quality, and promote the high-quality development of an aging society.

There are still some limitations in this study: it is difficult to explore the long-term dynamic impact of community home elderly care services on the social participation of the chronically ill elderly due to the selection of cross-sectional data for analysis. Since this study focuses on the three-dimensional mediation mechanisms of physical health, mental health, and social health of the chronically ill elderly, it is difficult to systematically grasp the complex mechanism of community home-based medical care services affecting social participation. In the digital era, digital technology has been fully integrated into all fields of the economy and society, and the smart elderly care service model has become increasingly popular. Digital participation has also become an important part of social participation. The relationship between community-smart elderly care services and the digital participation of the chronically ill elderly can be further studied.

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

HJ: conceptualization, data curation, methodology, validation, resources, writing—original and editing, and screening questionnaires and tables. ZL: supervision, project management, writing—original and editing, preparation conceptualization, and formal analysis. 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.

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Educational degree differences in the association between work stress and depression among Chinese healthcare workers: Job satisfaction and sleep quality as the mediators

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Background: Depressive status of medical personnel worldwide and especially in China is an important public health and social problem. There is a strong relationship between education and depression, but no studies have studied grouping healthcare workers (HCWs) with different educational degree to discuss whether there are differences in the factors that affect depression. This study aims to examine the role of job satisfaction and sleep quality in the relationship between work stress and depression among Chinese HCWs, and teste whether the mediation models are differed by the differences of educational degree.

Methods: Patient Health Questionnaire-9 (PHQ-9) scale was used to test depression. Work stress was assessed using the Challenge-blocking stress scale (CBSS). Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI). HCWs' satisfaction with their current work was assessed using the Job Satisfaction Index (JSI). The representative sample of HCWs was chosen using a multi-stage stratified cluster random sampling procedure and 844 HCWs were utilized to the statistical analysis of the study.

Results: In the overall sample, sleep quality could mediate the relationship between work stress and depression in healthcare workers ($p<0.001$, CMIN/DF=3.816, GFI=0.911, AGFI=0.886, IFI=0.943, TLI=0.933, CFI=0.942, RMSEA=0.058, SRMR=0.055, AIC=1039.144), and the mediating effect accounted for 36.5%. After grouping educational qualifications, the model with sleep quality and job satisfaction as mediating variables reported a better fit in the group with low educational qualifications. The intermediary effect accounted for 50.6 and 4.43%, respectively. The highly educated group only has sleep quality as an intermediary variable in the structural model, and the mediating effect accounted for 75.4% ($p<0.001$, CMIN/DF=2.596, GFI=0.887, AGFI=0.857, IFI=0.937, TLI=0.926, CFI=0.937, RMSEA=0.044, SRMR=0.056, AIC=1481.322).

Conclusion: In the overall sample, sleep quality could mediate the relationship between work stress and depression in HCWs. Among HCWs with technical secondary school education and below, job satisfaction can mediate the positive

relationship between work stress and depression, while this mediating effect is not significant among HCWs with college degree and above.

1. Introduction

As the world's most populous country, by the end of 2021, China had a total of nearly 14 million healthcare workers (HCWs) (1). One out of every 101 persons works in healthcare. HCWs are experiencing unprecedented workloads and challenges as demand for health care rises. Especially in recent years, the COVID-19 epidemic has devastated the world, putting significant strain on HCWs worldwide. HCWs represent the defense front lines who take care of patients every time a pandemic or an epidemic arises (2), and they operate under more intense strain than other employees. Prolonged exposure to work stress can result in depression in HCWs (3). Many studies have reported a high rate of depression among HCWs (4, 5). Among HCWs, depression is a prevalent mental illness with nuanced causes. A rate 2–3 times greater than the general population, over 30% of resident doctors and 20% of hospital-based nurses experience depression (6, 7). Factors that contribute to depression include work stress, chronic illness, the doctor-patient interaction, workload, job satisfaction, sleep quality, and loneliness (8–10). HCWs were predisposed to depression as a result of specific occupational traits. The depressive state of medical workers globally, particularly in China, is a major public health and social issue. We must now discover which factors may be beneficial in determining the most effective ways to enhance this phenomenon.

Chinese HCWs have generally experienced psychiatric emotional illnesses including depression. Depression, in addition to producing physiological problems, can also lead to serious psychological problems, such as suicide (11, 12). According to studies, anxiety/ depression was a factor in a total of 46 instances (45 females) of nurse suicides in China between 2007 and 2016 as well as 51 cases (16 females) of doctor suicides in China between 2008 and 2016 (11, 13). Of course, male doctors are no exception, and even more serious (13, 14). Nevertheless, due to the complexity of depression's pathophysiology and the paucity of effective treatments, there were few effective therapies (15). Additionally, there were numerous complicated elements that might contribute to depression, including cultural, psychological, and biological ones (15). In order to identify effective depression intervention solutions, it is imperative to continue researching the pertinent elements of depression.

Numerous researchers have found a link between job stress and depression, whether they used HCWs as their research subjects or other volunteers (8, 16). There were few studies, nevertheless, have been conducted to investigate the likelihood of a mediation association between occupational stress and depression among HCWs. The research has revealed a link between job satisfaction and depression among HCWs (17), as well as a link between work stress and job satisfaction (18). Among HCWs, studies have revealed a significant mediating role between mood exhaustion and social support between

work stress and depression (19), as well as the effects of job satisfaction and depression on willingness to leave (20). Quick et al. emphasized human psychology and mentality, which is the theoretical model of response theory, and hold that job stress is a reaction-based paradigm (21). This connected mental and mental health to stress at work. According to Robbins' model of stress theory (22), being under stress causes anxiety, depression, and decreased work satisfaction, which ties stress and job satisfaction together. Sleep issues frequently manifest before a new or repeated episode of severe depressive illness, according to research by Peter et al. (23). To summarize, it is essential to investigate the impact of job satisfaction and sleep quality in mediating the relationship between work stress and depression. There were indications that the association between work stress and depression may be influenced by job satisfaction and sleep quality. However, few studies have investigated the mediating role of job satisfaction between job stress and depression.

Poor mental health disorders like depression are frequently accompanied by poor sleep quality. Sleep problems are widespread illnesses that are very curable. The onset of a variety of adult mental problems is associated with sleep abnormalities (24), such as depression and anxiety. Numerous research, including those involving senior citizens and dentistry students, have confirmed the strong link between poor sleep and depression (25, 26). This connection has also been verified in HCWs (27). As nurses in many departments of health institutions have confirmed, sleep disorders were not only directly related to job stress but also inexorably connected to depression (28). However, it has not been researched, especially among this specific group of HCWs, if poor sleep quality can mediate the link between job stress and depression.

It is public knowledge that HCWs are generally more educated than other occupations. By the end of 2020, 15.1% of all the population in China had college degree or above, and 80.5% of all HCWs had college degree or above (29, 30). HCWs with college degree or above accounted for 5.3 times of the total population. Depression and educational attainment have been shown to interact in pregnant women (31). In South Korea's population aged 45 and older, education influenced depression through different underlying mechanisms, most notably through the development of cognitive abilities (32). A study found that among Chinese nurses, the degree of education had a statistically significant effect on depression (33). Community mental health care workers who were younger than 30 years, single, and received higher education showed higher depressive symptoms, and higher level of education may bring them more psychiatric issues during COVID-19 epidemic (34). Altogether, there was sufficient evidence to conclude that education was substantially connected with depression overall, and especially among HCWs.

In accordance with the content afore mentioned, there were insufficient presents the findings at how job satisfaction and sleep

quality affected the association between depression and work stress, especially among HCWs. There is a significant association between education and depression, and numerous researchers have found that those with higher levels of education were more likely to experience depression. However, no studies have compared groups of HCWs with various levels of education to determine whether there are variations in the factors that influence depression. Therefore, the following hypotheses are proposed in this study: (1) among Chinese HCWs, job satisfaction and sleep quality mediated the link between work stress and depression; (2) the mediation models were differed by the differences of educational degree. In the context of China's massive medical workforce and its increasingly severe depressive symptoms, identification of the factors that contribute to depression among HCWs and the mediating mechanisms can encourage administrators of hospitals and other medical institutions to take proactive and successful actions to reduce risk factors and strengthen protective factors. The management of medical institutions can develop efficient strategies to fulfill the various demands of medical staff members according to their varied educational backgrounds thanks to the disparities brought about by academic degrees.

2. Materials and methods

2.1. Participants

Data were gathered from the 2020 Household Health Interview Survey, which attempted to investigate the practice status and work status of doctors in primary medical institutions. It included information on basic personal information, work and assessment, job satisfaction, work stress, burnout, sleep quality and depression. The representative sample of HCWs was chosen using a multi-stage stratified cluster random sampling procedure, which combined multiple methodologies often employed in large-scale epidemiological sample surveys in order to get sampling results that are more representative of the real population. On-the-spot investigation was conducted in six counties (districts) of Tai'an City, Shandong Province, China. The investigating body comprised the corresponding village's community health service center, township health center, and its subordinate community health service station, or village clinic. First, three to four townships were randomly selected from each district (county) of Tai'an City using a probability sampling method proportional to the scale, according to the local economic development level and geographical position. Second, a total of 160 villages (communities) were randomly selected from each township (communities). Third, health providers were recruited from selected primary health facilities in each village (community). All general practitioners, village physicians, and other medical staff who were on duty or at the relevant institution on the same day were included as participants, as were those who were aware of the survey's purpose, gave their agreement willingly, and engaged in it. Individuals who found it difficult or impossible to communicate as well as those who refused to participate in the survey were excluded. We obtained informed consent from the respondents after thoroughly outlining the rationale for gathering their personal data and how it would be used. Each respondent was interviewed face-to-face by in-depth trained investigators for no less than 30 min.

The sample size was determined as follows:

$$N = \frac{\mu_\alpha^2 \times p(1-p)}{\sigma^2} \times deff$$

The confidence level was 95%, $\mu_\alpha = 1.96$, the relative error was 5%, $\sigma = 5\% \times 75\%$, and $deff = 1.5$. N = 768 was calculated. Decided on an invalid questionnaire rejection rate of 10% and a minimum sample size of 845. There were 860 questionnaires distributed in all, and 849 of them were returned, yielding a recovery rate of 98.72%. Five surveys with plenty of missing values were discarded. The survey data of the last 844 HCWs were utilized to the statistical analysis of the study. This project was approved by the Ethical Committee of Shandong University's Centre for Health Management and Policy Research (approval number: LL20191220).

2.2. Measures

2.2.1. Depression

The PHQ-9 (Patient Health Questionnaire-9) scale was applied in this research to assess depression. The PHQ-9 is a self-report screening instrument for depression symptoms containing nine items (3 points each) (35). The items of the PHQ-9 map onto the DSM-IV major depression criteria. The severity of the depression was indicated by the scale's higher score. Based on past validation studies in cohorts, a total score of 10 or higher was deemed predictive of depression (36). The PHQ-9 was a valid and reliable indicator of the severity of depression (35, 37, 38). The Cronbach's alpha coefficient of PHQ-9 scale in this study was 0.930, the Kaiser-Meyer-Olkin (KMO) value was 0.938, and the significance of the Bartley sphericity test was $p < 0.001$, which indicated good reliability and validity of PHQ-9.

2.2.2. Work stress

The Challenge-blocking stress scale (CBSS) developed by Professor Cavanaugh (39) was utilized in this study to assess work stress. The self-rating scale has 11 items in two categories, six of which are challenging stressors and five of which are obstructive stressors. Challenging stress comprised 6 topics, such as "TIME urgency I experience"; There were five categories of obstructive stress, such as "Inability to clearly understand your work standards." Likert 5 subscale was used in the questionnaire, with 1 ~ 5 representing "no pressure," "some pressure," "uncertain," "relatively pressure," and "very pressure" respectively. The participants had to assess how much stress had been brought on by the stressor over the previous 3 months considering their actual work environment. A higher score suggested that HCWs were under more stress. In this study, the demanding pressure scale's Kronbach's alpha coefficient was 0.901, with the challenging pressure's alpha coefficient being 0.923 and the blocking pressure's alpha coefficient being 0.875. The KMO value was 0.918, and the significance of the Bartley sphericity test was $p < 0.001$. The above results indicated good reliability and validity of the scale.

2.2.3. Sleep quality

The Pittsburgh Sleep Quality Index (PSQI), which measures subjective sleep quality throughout the preceding 1-month period, was used to measure the quality of sleep in this study. PSQI was compiled by Dr. Buysse, a psychiatrist at the University of Pittsburgh in 1989 (40). This scale is suitable for the evaluation of sleep quality of

patients with sleep disorders and mental disorders, and it is also suitable for the assessment of sleep quality of ordinary people. The PSQI consists of 19 self-rated questions. The 19 self-rated questions evaluate a wide range of sleep-related parameters, such as estimates of sleep duration and latency as well as the frequency and seriousness of sleep-related issues. Seven component scores, each weighted equally on a 0 ~ 3 scale, were created from these 19 elements. The global PSQI score, which ranges from 0 to 21, is then calculated by adding the seven component scores; higher numbers denote poorer sleep quality (40). Numerous investigations have utilized this scale, which has been found to have high reliability and validity (41). In this study, the Kronbach α coefficient of PSQI was 0.757, the KMO value was 0.741, and the significance of the Bartlett sphericity test was $p < 0.001$, which indicated good reliability and validity of PSQI.

2.2.4. Job satisfaction

HCWs' satisfaction with their current work was assessed using the tool developed by Schriesheim & Tsui (42), the Job Satisfaction Index (JSI). This instrument consists of a six-item questionnaire that is used to gauge how satisfied HCWs are with their current jobs. This test includes components that are identical to the aspects of job satisfaction: the nature of the work, supervision, coworkers, compensation, and promotion chances. A Likert scale of one (strongly disagree) to five (strongly agree) is included in the instrument. Higher scores indicate higher job satisfaction. Based on the previous investigation, the JSI scale was determined to be reliable with a Cronbach's alpha of 0.95 (42). The Cronbach's alpha for the current study was 0.893, the KMO value was 0.843, and the significance of the Bartlett sphericity test was $p < 0.001$, which indicated good reliability and validity of JSI.

2.2.5. Covariables

Ten covariates, including sociodemographic variables, were included in the statistical analysis. The participants' educational backgrounds were divided into two groups, technical secondary school and below and college and above. Gender was measured as male (0) and female (1). The participants' ages were calculated using their date of birth and divided into three groups, ≤44 years old belong to young people (0), ≥45 years old belonging to middle-aged and older adults (1). District was assessed as urban (0) and rural (1) areas. Individual annual income was assessed as less than RMB 30,000 (0) and RMB 30,000 or more (1). The length of medical service of HCWs was divided into less than 20 years (0) and more than or equal to 20 years (1). The number of hours worked per day by participants was divided into two categories, less than 10 h (0) and more than or equal 10 h (1). Whether or not HCWs have participated in professional work training was evaluated by no (0) and yes (1). Participants with or without commercial health insurance were assessed as no (0) and yes (1).

2.3. Statistical methods

All data analysis procedures for this investigation were carried out using SPSS, version 27.0. First, descriptive analysis was used to examine the mean and standard deviation of continuous variables and the number and proportion of categorical variables. One-way ANOVA and Chi-square analysis were conducted to assess mean differences for

variables across the educational qualifications. Second, one-way ANOVA was used to assess whether different categories of all covariates were different for depression. In this step, the overall situation, and the classification of educational degree were analyzed separately. Third, multiple regression was used to assess whether all covariates and continuous variables were statistically significant for depression. Similarly, in this step, the analysis of the overall situation and the classification of educational degree were made, respectively. To assess the average differences between various educational degrees, one-way ANOVA and chi-square analysis were utilized. Finally, Structural equation modeling (SEM) was employed *via* maximum likelihood using SPSS AMOS (version 26.0) to test the research model based on the data collected from HCWs in Tai'an City, Shandong Province, China.

There are several metrics that determine the degree of agreement between the hypothetical model and the observed data in structural equations. Typically, the root-mean-square error of approximation (RMSEA) of <0.08 means that the model is acceptable (43). In a model with a good fit, it is best to meet the following criteria: (1) the Goodness-of-Fit Index (GFI) should be greater than or equal to 0.90; (2) the Comparative Fit Index (CFI) should be greater than or equal to 0.90; (3) the Standardized Root Mean Square Residual (SRMR) should be less than or equal to 0.10; (4) Tucker Lewis Index (TLI) should be greater than 0.90 (44); (5) the Incremental Fit Index (IFI) should be greater than 0.90 (45); (6) the Adjusted Goodness-of-Fit Index (AGFI) should be greater than or equal to 0.80 (46). If the GFI does not reach 0.90 but is very close to 0.90, the fit of the structural model can still be considered acceptable if other indices are satisfied. Studies have decided this way (47).

3. Results

3.1. One-way ANOVA and Chi-square analysis of variables related to educational qualifications

The data from 844 HCWs in Tai'an, Shandong Province, China were included in the statistical analysis of this study. Among them, male participants accounted for 53.2%; 56.8% of participants were younger than 44 years old; the proportion of HCWs whose household registration was urban was 41.4%; the proportion of HCWs with an annual income of less than 30,000 yuan was 52.7%; the proportion of participants with chronic diseases was much smaller than that of those who do not have chronic diseases, accounting for less than a quarter (19.1% vs. 80.9%), and so on. More detailed data as well as other categorical variables are given in Table 1. Table 1 expounds that all 9 covariates were statistically significant for academic qualifications ($p < 0.001$ or $p < 0.05$). Participants scored a mean score of 35.20 on work stress (standard deviation = 7.97); The average score for job satisfaction was 18.85 (standard deviation = 5.48); The average score for sleep quality was 6.23 (standard deviation = 3.41); The mean score for depression was 5.34 (standard deviation = 4.72). Except for depression, which was significantly different in educational qualifications ($p < 0.05$), work stress, job satisfaction, and sleep quality were not statistically significant on educational qualifications ($p \geq 0.05$).

Variables	Overall	Technical secondary school or below	College degree or above	F/χ^2
Gender				61.046[a],***
Male	449 (53.2)	279 (62.1)	170 (37.9)	
Female	395 (46.8)	139 (35.2)	256 (64.8)	
Age				36.089[a],***
<44	479 (56.8)	194 (40.5)	285 (59.5)	
≥45	365 (43.2)	224 (61.4)	141 (38.6)	
Resident				147.404[a],***
Urban	349 (41.4)	86 (24.6)	263 (75.4)	
Rural	495 (58.6)	332 (67.1)	163 (32.9)	
Income				76.939[a],***
<30,000	445 (52.7)	284 (63.8)	161 (36.2)	
≥30,000	399 (47.3)	134 (33.6)	265 (66.4)	
Chronic				19.596[a],***
Yes	161 (19.1)	105 (65.2)	56 (34.8)	
No	683 (80.9)	313 (45.8)	370 (54.2)	
Medical working years				27.218[a],***
<20	310 (36.7)	117 (37.7)	193 (62.3)	
≥20	534 (63.3)	301 (56.4)	233 (43.6)	
Daily working hours				66.720[a],***
≤10 h	390 (46.2)	134 (34.4)	256 (65.6)	
>10 h	454 (53.8)	284 (62.2)	170 (37.4)	
Attend training				13.278[a],***
No	99 (11.7)	32 (32.3)	67 (67.7)	
Yes	745 (88.3)	386 (51.8)	359 (48.2)	
Commercial insurance				4.227[a],*
No	609 (72.2)	315 (51.7)	294 (48.3)	
Yes	235 (27.8)	103 (43.8)	132 (56.2)	
CBSS	35.20 ± 7.97	35.68 ± 8.26	34.73 ± 7.65	3.016
JSI	18.85 ± 5.48	18.74 ± 5.60	18.96 ± 5.37	0.335
PSQI	6.23 ± 3.41	6.03 ± 3.47	6.42 ± 3.34	2.855
PHQ	5.34 ± 4.72	4.96 ± 4.79	5.70 ± 4.63	5.182*

CBSS, Challenge-blocking stress scale; JSI, Job Satisfaction Index; PSQI, Pittsburgh sleep quality index; PHQ, Patient Health Questionnaire-9.

[a]Expected count of 0 cells is less than 5.

*$p < 0.05$; ***$p < 0.001$.

3.2. One-way ANOVA of covariables related to depression

When the academic qualifications of HCWs were not classified, the only covariate associated with depression was whether they had chronic diseases ($F = 2.198$, $p = 0.001$). When classifying the educational qualifications of medical personnel, the covariate associated with depression in the relatively low educational group was whether they had attended business training or not ($F = 1.882$, $p = 0.011$). In the relatively highly-educated group, the covariate associated with depression was whether interviewees have chronic diseases or not ($F = 2.939$, $p < 0.001$).

3.3. Multiple regression analysis of variables related to depression

When participants were not grouped by academic qualification, variables associated with depression were age ($B = -0.688$, $p = 0.029$), household registration ($B = -0.952$, $p = 0.001$), annual personal income ($B = -0.57$, $p = 0.029$), work stress ($B = 0.130$, $p < 0.001$), job satisfaction ($B = -0.049$, $p = 0.029$), and sleep quality ($B = 0.765$, $p < 0.001$). After grouping HCWs' educational qualifications, age in either group was not statistically significant with depression ($p > 0.05$). In the group with relatively low educational qualifications, depression was associated with personal annual income ($B = -0.828$, $p = 0.031$), job stress ($B = 0.154$, $p < 0.001$), job satisfaction ($B = -0.089$, $p = 0.006$), and sleep quality ($B = 0.689$, $p < 0.001$). In the group with relatively high educational qualifications, depression was associated with household registration ($B = -1.273$, $p = 0.001$), chronic disease ($B = -1.573$, $p = 0.002$), work stress ($B = 0.104$, $p < 0.001$) and sleep quality ($B = 0.834$, $p < 0.001$). More detailed data analysis results are shown in Table 2.

3.4. The mediating role of job satisfaction and sleep quality in the relationship between work stress and depression

In this step, the mediation model was established for all participants' data samples (recorded as model 1), and then the mediation model is constructed after the academic qualifications were classified (recorded as model 2).

Work stress and sleep quality were statistically significant for depression when HCWs' educational qualifications were not classified, while job satisfaction was not statistically significant for depression ($B = -0.045$, $p = 0.123$). Sleep quality had a significant incomplete mediating effect between work stress and depression, and the mediating effect accounted for 36.5%. However, job satisfaction did not mediate the relationship between work stress and depression, for job satisfaction was not significant for depression. The results about their relationship and 95% confidence intervals are all presented in Table 3. The model diagram of Model 1 is shown in Figure 1. Model 1 reported good fit of the mediating effect model, as detailed in Table 4.

Work stress ($B = 0.247$, $p = 0.009$), sleep quality ($B = 0.598$, $p = 0.007$), and job satisfaction ($B = -0.097$, $p = 0.022$) all exhibited significant impacts on depression in model 2 and when respondents' educational levels were technical secondary school or below. Additionally, work stress had statistically significant negative impacts on both job satisfaction ($B = -0.251$, $p = 0.009$) and sleep quality ($B = 0.465$, $p = 0.010$; The PSQI scale score was significantly positively impacted by the Challenge-blocking stress scale score). The relationship between work stress and depression can be mediated by both sleep quality and job satisfaction. The

TABLE 2 Multiple regression analysis of variables related to depression.

Variables	Total				Educational degree[a]				Educational degree[b]			
	B	p	95% CI		B	p	95% CI		B	p	95% CI	
			LB	UB			LB	UB			LB	UB
Gender	0.41	0.114	−0.098	0.918	0.704	0.068	−0.053	1.461	0.066	0.85	−0.624	0.757
Age	−0.668	**0.029**	−1.267	−0.069	−0.608	0.174	−1.485	0.269	−0.457	0.274	−1.279	0.364
Resident	−0.952	**0.001**	−1.494	−0.41	−0.513	0.252	−1.392	0.366	−1.273	**0.001**	−2.018	−0.529
Income	−0.57	**0.029**	−1.083	−0.058	−0.828	**0.031**	−1.582	−0.074	−0.502	0.166	−1.213	0.21
Chronic	−0.46	0.141	−1.072	0.152	0.276	0.498	−0.525	1.078	−1.573	**0.002**	−2.546	−0.601
Medical working years	0.305	0.33	−0.31	0.92	−0.284	0.566	−1.255	0.687	0.544	0.173	−0.239	1.328
Daily working hours	−0.261	0.306	−0.76	0.239	−0.17	0.659	−0.927	0.587	−0.346	0.312	−1.017	0.326
Attend training	0.015	0.968	−0.732	0.763	−1.246	0.061	−2.55	0.059	0.567	0.21	−0.321	1.455
Commercial insurance	−0.254	0.344	−0.779	0.272	−0.626	0.129	−1.433	0.182	−0.01	0.977	−0.689	0.669
Work stress	0.130	**<0.001**	0.097	0.164	0.154	**<0.001**	0.106	0.201	0.104	**<0.001**	0.057	0.151
Job satisfaction	−0.049	**0.029**	−0.094	−0.005	−0.089	**0.006**	−0.152	−0.026	−0.011	0.739	−0.073	0.052
Sleep quality	0.765	**<0.001**	0.69	0.84	0.689	**<0.001**	0.58	0.797	0.834	**<0.001**	0.732	0.936

Bold values are denotes statistically significant. CI denotes to confidence interval, LB denotes to lower bound, UB denotes to upper bound. [a]Denotes to technical secondary school or below.
[b]Denotes to college degree or above.

TABLE 3 Standardized effects and 95% CI.

Grouping situation	Paths	Beta coefficient	p	95%CI	
				Lower	Upper
Total	Work stress → Sleep quality	0.413	0.012	0.337	0.493
	Sleep quality → Depression	0.703	0.007	0.659	0.759
	Work stress → Job satisfaction	−0.319	0.006	−0.401	−0.225
	Job satisfaction → Depression	−0.045	0.123	−0.094	0.000
	Work stress → Depression	0.167	0.006	0.109	0.234
Educational Degree[a]	Work stress → Sleep quality	0.465	0,01	0.300	0.604
	Sleep quality → Depression	0.598	0.007	0.497	0.693
	Work stress → Job satisfaction	−0.251	0.009	−0.351	−0.115
	Job satisfaction → Depression	−0.097	0.022	−0.164	−0.026
	Work stress → Depression	0.247	0.009	0.144	0.330
Educational Degree[b]	Work stress → Sleep quality	0.389	0.007	0.257	0.542
	Sleep quality → Depression	0.788	0.006	0.718	0.858
	Work stress → Job satisfaction	−0.392	0.009	−0.497	−0.250
	Job satisfaction → Depression	0.006	0.817	−0.076	0.104
	Work stress → Depression	0.099	0.048	0.003	0.223

CI denotes to confidence interval, LB denotes to lower bound, UB denotes to upper bound. [a]Denotes to technical secondary school or below.
[b]Denotes to college degree or above.

mediating effect between the relationships between the effects of sleep quality on them was 50.6%, while the mediating effect between the relationships in which job satisfaction affected them was 4.4%. In Model 2 and when respondents had a college degree or above, work stress ($B = 0.099$, $p = 0.048$) and sleep quality ($B = 0.788$, $p = 0.006$) significantly affected depression. What's more, sleep quality ($B = 0.389$, $p = 0.007$) and job satisfaction ($B = −0.392$,

$p = 0.009$) were affected by work stress. Job satisfaction was not significant for depression ($B = 0.006$, $p = 0.817$). Sleep quality may be utilized to mediate the association between work stress and depression, whereas job satisfaction cannot. The mediating effect between the relationships between the effects of sleep quality on them was 75.4%. Table 3 shows the details of the results and 95% confidence intervals of the relationships among the variables after
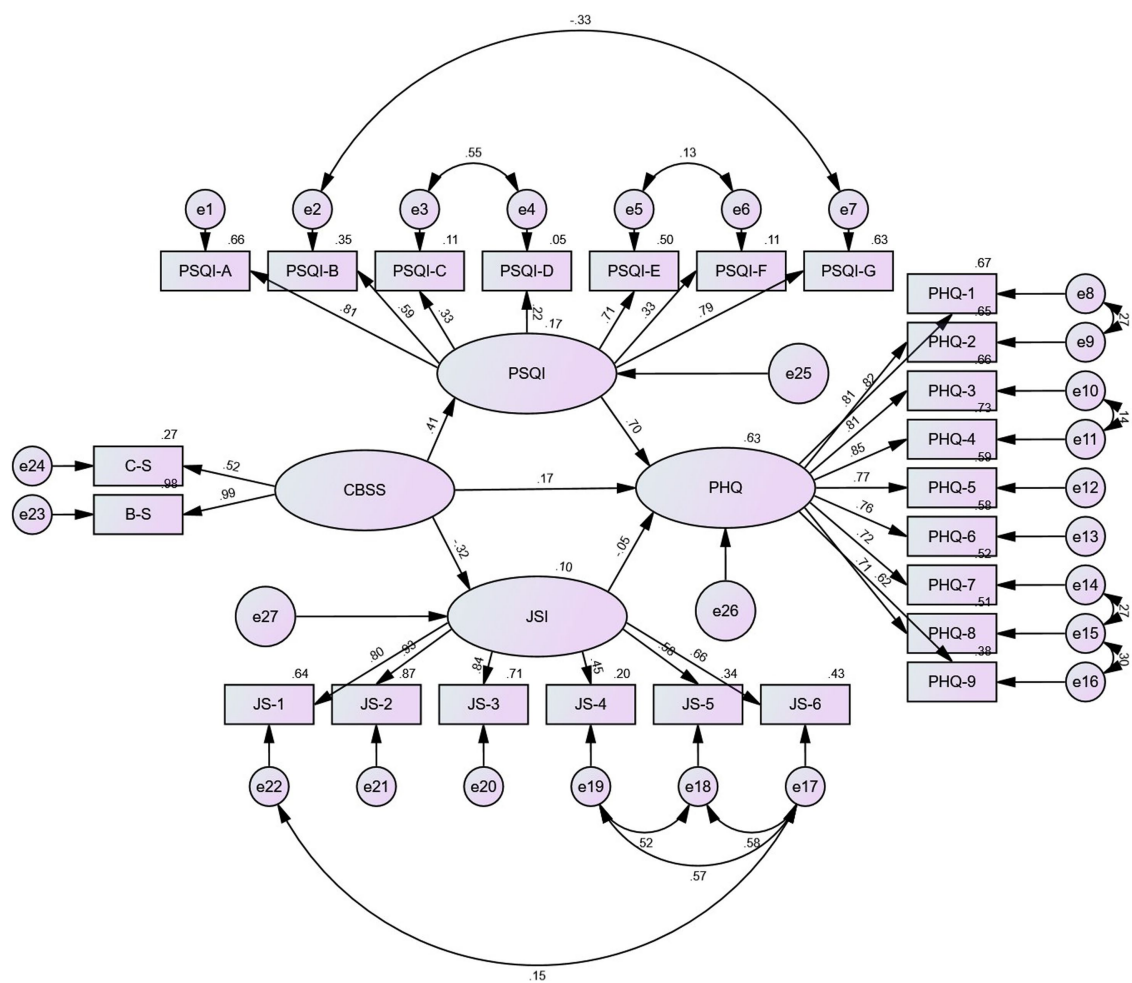
FIGURE 1
Results of the SEM analysis of the effects of sleep quality and job satisfaction mediate the association between work stress and depression among the whole sample. All the coefficients in the figure are standardized and significant at 0.001 level. Except that the path coefficient of JSI to PHQ is insignificant ($p \geq 0.05$).

TABLE 4 Goodness-of-fit statistics for the multiple group analysis based academic qualifications difference in model 1 and fit indices of model 2.

Models		p	CMIN/DF	GFI	AGFI	IFI	TLI	CFI	RMSEA	SRMR	AIC
Model 1	Total	<0.001	3.861	0.911	0.886	0.943	0.933	0.942	0.058	0.0545	1039.144
Model 2	Unconstrained	<0.001	2.596	0.887	0.857	0.937	0.926	0.937	0.044	0.0557	1481.322
	Measurement weights	<0.001	2.557	0.885	0.86	0.936	0.928	0.936	0.043	0.0564	1473.897
	Structural weights	<0.001	2.567	0.883	0.859	0.935	0.927	0.934	0.043	0.0588	1481.612
	Structural covariances	<0.001	2.566	0.883	0.86	0.935	0.927	0.934	0.043	0.0606	1481.788
	Structural residuals	<0.001	2.572	0.882	0.859	0.934	0.927	0.934	0.043	0.0603	1486.622
	Measurement residuals	<0.001	2.678	0.872	0.856	0.924	0.922	0.924	0.045	0.0642	1563.304

CMIN denotes to chi square, DF denotes to degree of freedom.

the grouping of educational degree. The data analysis results presented in Table 4 indicates that the grouping intermediary model had a good fitting degree. The findings of the multiple group analysis demonstrated that the model with "restricted measurement weights" and that with "restricted structural weights" had significantly different goodness-of-fit statistics (see Table 4). This finding revealed that among HCWs with various educational backgrounds, there were differences in the correlations between work stress, depression, sleep quality, and job satisfaction. Figures 2, 3 show the precise findings of these correlations amongst HCWs with various academic backgrounds. Among them, Figure 2 shows the results of model diagrams with technical secondary school education and below, and Figure 3 reveals the results of model diagrams with college degree or above.
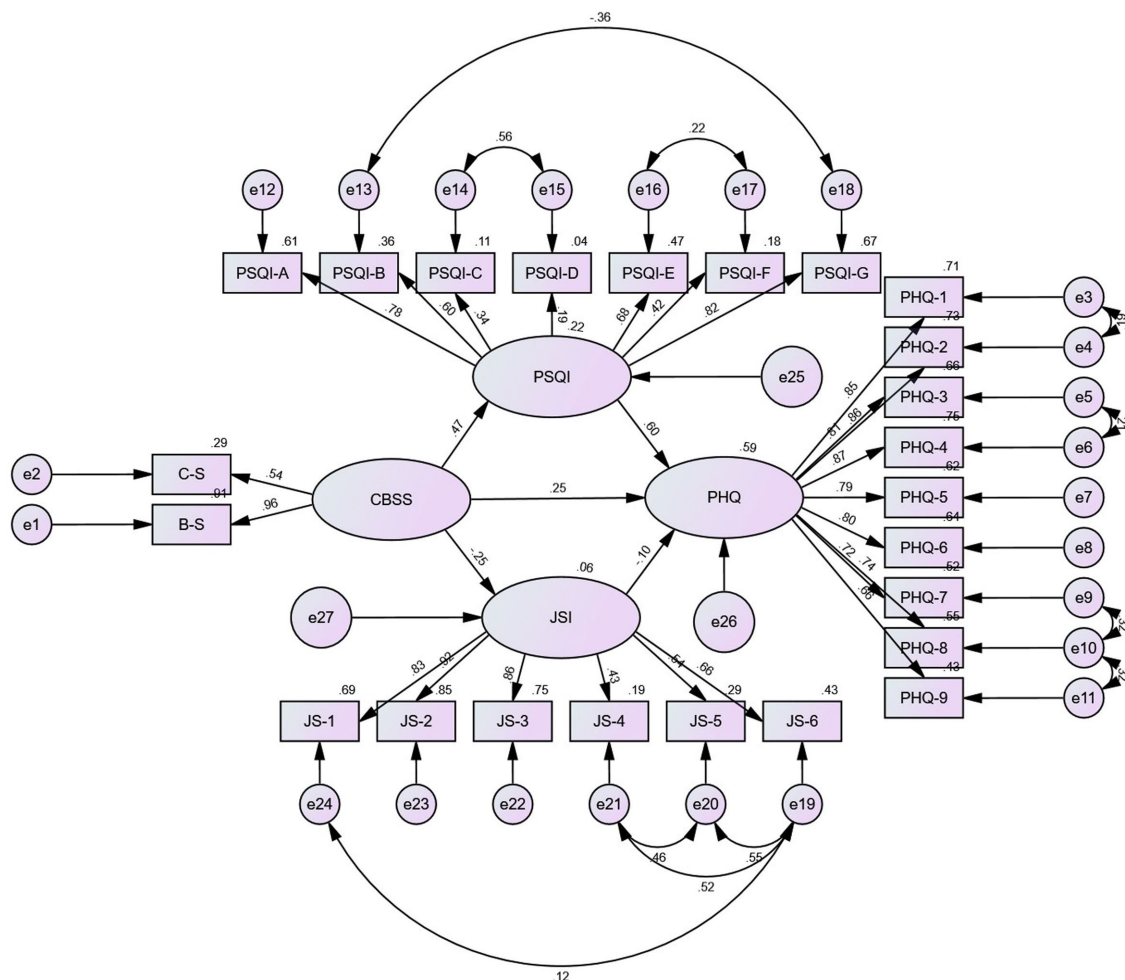
FIGURE 2
Results of the SEM analysis of the effects of sleep quality and job satisfaction mediate the association between work stress and depression among the sample of technical secondary school and below. All the coefficients in the figure are standardized and significant at 0.001 level. Except that the standardized coefficient of JSI to PHQ is significant at the level of 0.05.

4. Discussion

The work stress, depression, sleep quality, and job satisfaction of HCWs were assessed using a sample of 844 HCWs and relevant questionnaires. More importantly, the aim of this study was to investigate the relationship between work stress and depression in HCWs, to further explore the mediating roles of sleep quality and job satisfaction in this relationship, and to compare whether there are variations in the patterns of mediation among HCWs with various educational backgrounds. The findings substantially confirmed the hypotheses overall. This research revealed that sleep quality may moderate a favorable relationship between job stress and depression in HCWs. For HCWs with technical secondary school education and below, job satisfaction can moderate the positive connection between work stress and depression, but this mediation effect was not significant among HCWs with college degrees and above.

It is not new for health care workers that work stress can affect depression levels. Studies have demonstrated their relationship (16, 48). This significant link is undeniable, even within other groups (49). Pressure in the working environment, frequent changes of workplace, time-oppressive work, and irregular schedules such as shifts and staying up late are the major causes of high work pressure for HCWs. These negative factors markedly raise the possibility of occupational depression in HCWs. In addition, work stress may pose an even higher risk for depression by eroding their sense of personal control and feelings of self-worth (50, 51). According to this study, this effect was more pronounced among HCWs with less education than those with more education (0.247 vs. 0.099). However, depression was worse among highly educated HCWs (5.70, SD = 4.63 vs. 4.96, SD = 4.79; $p < 0.05$). Work stress with different educational qualifications is not significant. Greater educated HCWs may be better equipped to mitigate the negative impacts of work stress on depression because of their longer education, higher level of professional expertise, and ability to do so, but they also have a higher chance of developing depression due to other causes. One fashionable view, for instance, is that depression is a "genius disease." According to studies, more than 75% of poets and 50% of painters experience depression (52). Also, a survey of PhDs discovered that 45% of them had experienced depression (53). Understanding this issue could be made easier by the "cap" impact that education has on mental health. In other words, a mismatch between a high level of education and the demands of the workplace will result in psychological stress, disappointment, and despair, which in turn raises the risk of depressive episodes (54).
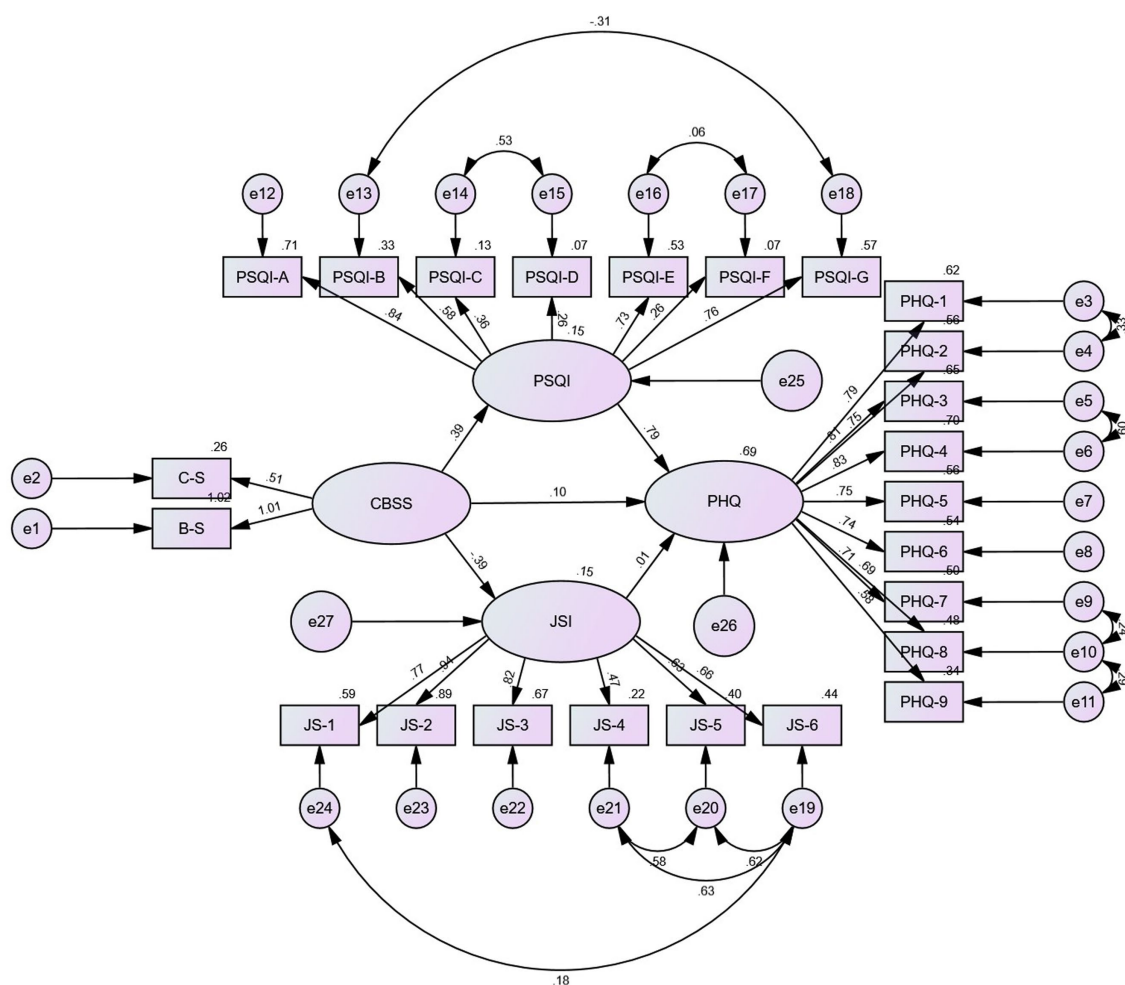
FIGURE 3
Results of the SEM analysis of the effects of sleep quality and job satisfaction mediate the association between work stress and depression among the sample of college degree or above. All the coefficients in the figure are standardized. The standardized coefficients of CBSS to JSI, CBSS to PSQI and PSQI to PHQ are significant at 0.001 level, CBSS to PHQ is significant at 0.05 level, and JSI to PHQ is not significant.

This study demonstrated a positive effect between work stress and sleep quality, which was consistent with the existing findings (28, 55). Researchers continue to identify putative mechanisms by which stress affects sleep, even though the mechanism by which job stress causes insomnia is unclear (56). The strain of working night shifts and long hours may contribute to sleep problems, which can exacerbate a number of physical and mental health disorders and diminish one's productivity (28). Sleep disturbance is the core influencing factor of depression and is also the core symptom. Insomnia in people who are not depressed has been linked in epidemiological studies to a later risk of developing depression (57). A controlled, double-blind study complemented the evidence that treating insomnia reduced the severity of depression and accelerated recovery (23). The aforementioned information may also assist in comprehending how sleep quality influences the link between depression and work stress. This study discovered that the educational background of HCWs had no bearing on the mediating connection; in other words, the mediating role has always persisted regardless of educational background.

The association between work stress and job satisfaction has been the topic of theoretical proposals, empirical investigations, and meta-analyses. This study established a substantial negative correlation between job stress and job satisfaction among HCWs. Specifically, higher work stress was associated with lower satisfaction levels. This was consistent with the relatively new view of many scholars in other populations (58–60). This relationship has also been demonstrated in the HCWs (8). However, few articles have examined the mediating role of job satisfaction between job stress and depression, let alone explored this mediating role in HCWs. In this study, the mediating role of job satisfaction was examined. Job satisfaction was observed to moderate a positive link between work stress and depression among medical practitioners with technical secondary school education or less, but this mediating correlation was not detected in those with college degrees or higher education. Lower educated healthcare professionals' job satisfaction was substantially correlated with depressive symptoms; highly educated individuals did not confirm this correlation. The reason may be that job satisfaction plays an important role in a group of low educational qualifications as a determinant of personal well-being (61). Increased personal wellbeing and low depression are both results of high job satisfaction. For those with greater levels of education, work satisfaction may no longer play

the most crucial role in determining their level of personal wellbeing. Higher education often translates into more and deeper professional knowledge, which makes medical professionals with higher education more self-demanding and consequently more knowledgeable about the complex causes of depression. As a result, work satisfaction is not a good indicator of depression.

Altogether, work stress was strongly associated with depression. Among HCWs with technical secondary school education and below, sleep quality and job satisfaction could mediate a positive relationship between work stress and depression. Among HCWs with a college degree or above, only sleep quality could be used as a mediating variable in the relationship between work stress and depression. HCWs frequently operate in circumstances that are riskier, more unpredictable, and more complicated than those encountered by other employees, particularly considering the recent deterioration in doctor-patient communication. HCW depression at work is a significant public health issue that needs to be addressed but is still underdiagnosed and undertreated. Effective medication management may lower the incidence of severe depressive episodes or improve the ability of people at risk to handle stress at work. The promotion of workplace mental health has been considered as one method of promoting economic growth and maintaining the sustainability of overburdened social welfare systems. Primary prevention may be a viable technique to promote mental health in the workplace. To lessen the prevalence of depression in the workplace, basic preventative strategies as well as high-quality therapies provided by primary care, occupational health, and mental health specialists can be implemented. Regardless of the educational background of the HCWs, lowering work stress can encourage better sleep, which reduces the probability of depression. Policies and actions to lessen the stress on HCWs and enhance sleep quality should be on the agenda of governments and pertinent institutions. Higher educated HCWs report more severe depression, yet little research or effective treatment exists for their depression. Comparatively to less educated health professionals, job satisfaction is not a reliable indicator of depression, thus it's critical to identify other risk factors and take steps to address them. By improving job satisfaction for HCWs with lower academic qualifications, the risk of depression can be decreased while also enhancing their sense of success and belonging to the institution. In the meanwhile, investigating other aspects in their depression development is equally important and ought to be on the agenda.

There are several limitations to this study worth considering. First, the cross-sectional study could not verify the causal relationship between the variables, nor could it assess the development trend of depression in healthcare workers. Future studies can follow up on a fixed sample of respondents to form longitudinal data to verify the relationship more rigorously between variable cause and effect. Second, the results of this study were derived from only one city, which may limit the generalization of the results among the wider HCWs. Subsequent studies can verify the results of this study by expanding the random sampling range. Third, the content of this survey was self-reported by the target population, and it is difficult to avoid the existence of recall bias.

5. Conclusion

The main contributions of this study are: (1) the establishment of a mediating model for the relationship among work stress, sleep quality, and depression among Chinese HCWs; and (2) the discovery that job satisfaction, in groups from technical secondary school and below, mediates the association between work stress and depression. However, this mediating role is not found in groups from colleges and above. The government and relevant ministries should pay attention to and improve the workplace in order to reduce the workload of HCWs, promote sleep quality, and diminish the chance of depression. At the same time, they should increase the job satisfaction of low-educated staff, research the variables influencing depression in highly educated medical staff, and implement proactive and successful depressive disorder prevention strategies.

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 Ethical Committee of the Centre for Health Management and Policy Research, Shandong University (approval number: LL20191220). The patients/participants provided their written informed consent to participate in this study.

Author contributions

All the authors participated in this research. Data analysis and manuscript writing were all completed by AQ. Data was collected by FH, WQ, YD, and ML. The revision of the manuscript was done by AQ, FH, and LX. 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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What has affected the governance effect of the whole population coverage of medical insurance in China in the past decade? Lessons for other countries

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Objective: This study aimed to explore the current state of governance of full population coverage of health insurance in China and its influencing factors to provide empirical references for countries with similar social backgrounds as China.

Methods: A cross-sectional quantitative study was conducted nationwide between 22 January 2020 and 26 January 2020, with descriptive statistics, analysis of variance, and logistic regression models *via* SPSS 25.0 to analyze the effectiveness and influencing factors of the governance of full population coverage of health insurance in China.

Results: The effectiveness of the governance relating to the total population coverage of health insurance was rated as good by 59% of the survey respondents. According to the statistical results, the governance of the public's ability to participate in insurance (OR = 1.516), the degree of information construction in the medical insurance sector (OR = 2.345), the government's governance capacity (OR = 4.284), and completeness of the government's governance tools (OR = 1.370) were all positively correlated ($p < 0.05$) on the governance effect of the whole population coverage of health insurance.

Conclusions: The governance of Chinese health insurance relating to the total population coverage is effective. To effectively improve the effectiveness of the governance relating to the total population coverage of health insurance, health insurance information construction, governance capacity, and governance tools should be the focus of governance to further improve the accurate expansion of and increase the coverage of health insurance.

KEYWORDS

medical insurance, population coverage, medical insurance governance, governance effect, influence factors

Background

The actualization of health insurance population coverage (HIPC) is one of the biggest challenges facing global health development and is one of the essential health system reforms and development goals advocated by the World Health Organization (WHO) (1). Relevant studies showed that, in 2019, the average effective coverage rate of the global insured population was 60.3% and more than one-third of the world's population still lacked health insurance (2). In the past decade, through its governance of the medical insurance sector, China rapidly increased the average effective coverage rate of its insured population from <30% in 2000 to ∼95% in 2010 and has maintained this level to this day (3–6). There is no denying that, as a typical developing country, China has a large population and complex structure where the productivity level is not high, yet, in the shortest possible time, it successfully completed the most expansive HIPC (7, 8). Chinese HIPC governance and its experience, compared with other countries with similar social backgrounds, has received worldwide recognition and high reference value and is worth examining.

Although China has maintained a high level of health insurance population coverage in recent years, still ∼80 million people are not covered by health insurance. This phenomenon has continued since 2010. Therefore, to understand the effectiveness of HIPC governance in China in recent past, an in-depth analysis of the factors affecting the efficacy of HIPC governance has become essential for further coverage of the HIPC in China. HIPC governance effectiveness refers to the systematic or singular results produced by the party and government as the core governing body through a series of systematic arrangements and the combined use of composite governance tools and instruments in HIPC. China's efforts in the last decade in the governance of full population coverage of health insurance have led the country to achieve 95% population coverage of health insurance in 2018 alone. However, the special nature of the voluntary principle of participation has impacted the governance of the whole population coverage, calling for the need to focus on the structure of the uninsured population even while acknowledging the increase in the number of people covered by health insurance. Effective governance of health insurance coverage for the entire population should be demonstrated not just by the fact that the majority of the population is insured but also to ensure that the uninsured do not choose to be insured because they are unable to afford health insurance premiums.

Naser Derakhshani (9), Dorjsuren Bayarsaikhan (10), Chhabi L. Ranabhat (11), Gulbiye Yenimahalleli Yasar (12), Ngan Do (13), and other scholars, in a systematic review of the process involved in the HIPC, suggested that social infrastructure, government participation, subject governance capacity, and the choice of instruments and tools were important factors that affect the effectiveness of HIPC governance. A review of the existing studies revealed that most scholars have mainly explored the factors affecting the effectiveness of HIPC governance from the government's perspective. The effectiveness of HIPC governance is

also closely related to the governance of individual factors. Studies have shown that the lower affordability of health insurance for the uninsured population is a major factor affecting the achievement of HIPC in most countries such as Vietnam, which has a high uninsured rate of 75% among the poor, and Kenya, which has the highest uninsured rate of 97% among the poor (14–16). The latest data from the China Health and Nutrition Survey (CHNS) also showed that 47% of the uninsured were unable to enroll due to insufficient ability to pay for health insurance, which confirms that it is not only government factors but also individual factors that affect the effectiveness of HIPC governance in China. However, many of the current literature focuses on the influence of specific factors and lacks a comprehensive analysis of HIPC governance from a holistic perspective. Therefore, based on the comprehensive analysis framework of "Government Factors—Governance of Individual Factors," this study aimed to explore the factors that influence the effectiveness of HIPC governance holistically.

In this study, we aimed to evaluate the governance effectiveness of HIPC in China, comprehensively explore the factors that significantly affect the governance effectiveness of HIPC in China, share important lessons learned from China's move toward HIPC, and provide empirical references for other countries with similar socio-historical backgrounds as China to achieve HIPC in their respective countries in the future.

Materials and methods

Study design

This study used a cross-sectional questionnaire to analyze the effectiveness of HIPC governance in China and the factors influencing it. Before the formal survey, a pre-survey was conducted, and 80 questionnaires were collected using a convenience sampling method to improve the quality of our design and questionnaire. The cross-sectional quantitative study was conducted nationwide between 22 January 2020 and 26 January 2020 using a purposive sampling method through the Questionnaire Star platform, a widely recognized online questionnaire platform in China, influenced by the outbreak of coronavirus (COVID-19). For research fit, the sample population eligible for the study had to meet the following conditions: The survey population had to be familiar with health insurance, be fully aware of the dynamics of health insurance policies, and understand the effects of policy implementation. To ensure the representativeness and validity of the original data, managers and staff of health insurance and its related departments, and academics whose research field is health insurance and its related fields were selected as the respondents of the survey, and their questionnaire results were used as the sample data.

The introductory section of the questionnaire required written informed consent before proceeding further. According to the IP address recorded on the questionnaire, each participant could only answer once. If a questionnaire was completed in 8 min or more, which was the minimum time our team tested to complete the questionnaire, and logically answered two questions, it was judged valid and included in the analysis; otherwise, it was removed. In

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Abbreviations: HIPC, Health insurance population coverage.

the end, 2,000 questionnaires were distributed in this study and 1,975 valid questionnaires were returned, with an effective rate of 98.75%.

Data extraction

To measure the governance of HIPC in China, respondents were asked "How effective do you think the governance of universal health coverage is at present?". The question was evaluated by setting the options to "not at all effective, not very effective, average, relatively effective, very effective." Using multiple logistic regression, the dependent variable (HIPC governance) was divided into two categories, with 0 indicating not very effective (selecting "not at all effective" and "not very effective") and 1 indicating effective (selecting "average," "relatively effective," "very effective").

The governance of individual factors included two key areas: governance in the area of participant awareness and governance in the area of participant capacity. In the survey, respondents were asked the following questions to measure the effectiveness of governance in the two areas of participant awareness and participant participation: "What is the level of governance for participant awareness in the HIPC governance process?" (low = 0; high = 1) and "How well is the governance of participation capacity in the HIPC governance process?" (low = 0; high = 1).

The government factor consisted of five major indicators: the degree of clarity of the government's governance functions, the degree of medical insurance information sharing between regions, the degree of information technology construction in the medical insurance sector, the government's governance capacity, and the completeness of governance tools. These factors were assessed through the survey respondents' answers to the following questions, respectively: "Do you think there is clarity in the government's role in the HIPC governance process?" (Unclear = 0; Clarity = 1); "Does your region share health insurance information with other regions?" (not achieved = 0, achieved = 1); "How well do you think China's medical insurance is currently being informalized?"; "How well do you think the government currently governs HIPC in the area of health care?"; and "How complete do you think our HIPC governance tools are?". The answers to the last three questions ranged from 0 to 5, with higher scores for a higher level of information technology, higher governance capacity, and better completeness of governance tools. In multiple logistic regression, the three dependent variables were scored as 1–2 for low-level, poor capacity, and incomplete groups, 3 for medium-level, general capacity, and general completeness groups, and 4–5 for high-level, high capacity, and completeness groups.

Variable selection

Control variable

HIPC governance effectiveness, as a subjective evaluation, is influenced by personal characteristics such as personal preference and temperament. Considering the representativeness of the sample, this study selected individual characteristic variables,
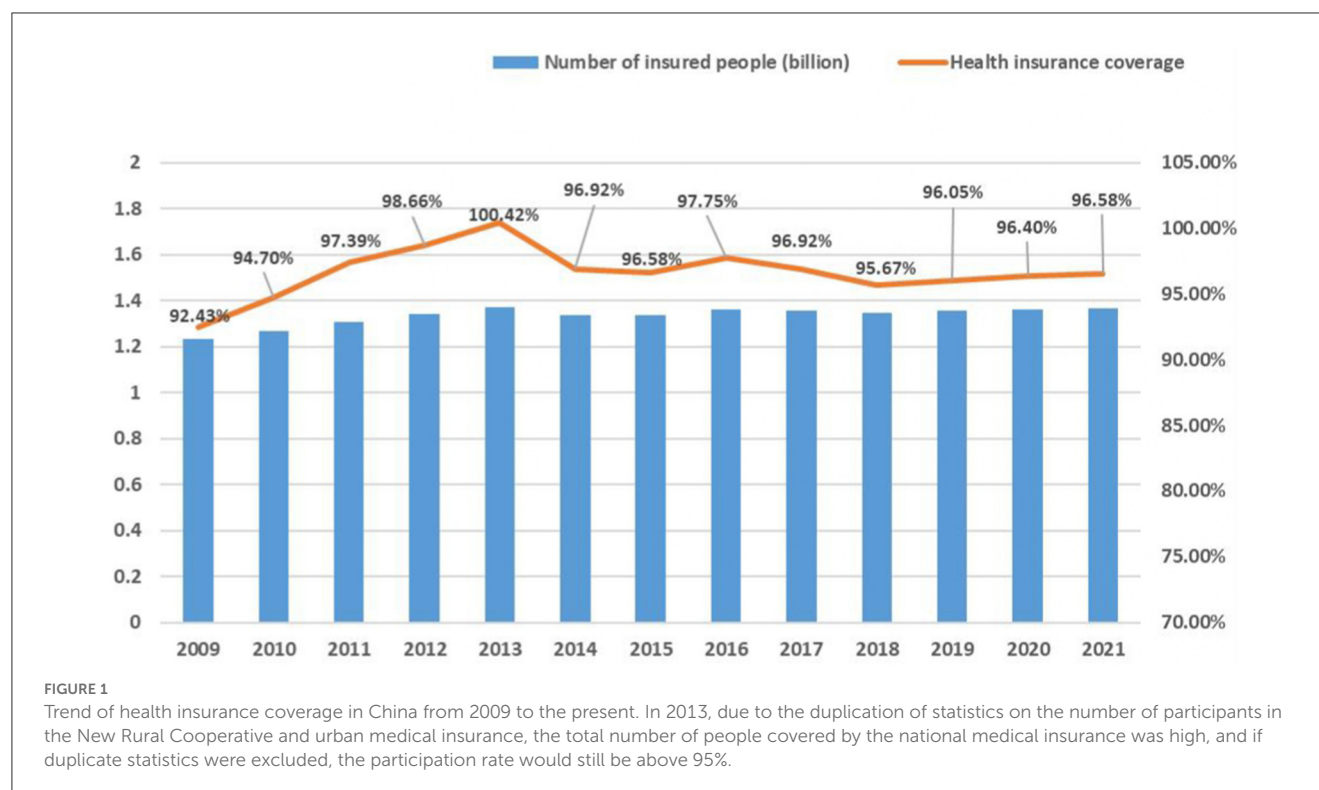
TABLE 1 Selection and description of variables.

Variable	Control group
Dependent variable	
HIPC governance status	0 = bad; 1 = good
Control variable	
Sex	0 = Men; 1 = Women
Age	Numerical variable
Educational level	1 = Tertiary and below; 2 = Undergraduate degree; 3 = Masters Degree; 4 = Doctoral degree
Type of profession	0 = Non-Medicare related professions; 1 = Medical insurance or medical insurance-related professions
Type of unit	0 = Medical insurance sector; 1 = Medical insurance related departments
Explaining variable	
Governance of individual factors	
Governance of the population's awareness of insurance participation	0 = low; 1 = High
Governance of people's ability to participate in insurance	0 = low; 1 = High
Government factors	
Clarity of government's governance functions	0 = Unclear; 1 = Clarity
The degree of medical insurance information sharing between regions	0 = Not achieved; 1 = Achieved
The degree of information technology construction in the medical insurance sector	1 = Low level; 2 = General; 3 = High level
Government's governance capacity	1 = Poor ability; 2 = General; 3 = High ability
Governance tools completeness	1 = Incomplete; 2 = General; 3 = Complete

controlling for gender, age, education, profession, and type of unit. The specific variable assignments are shown in Table 1.

Explaining variable

In this study, HIPC governance was used as the dependent variable. The explanatory variables mainly included (1) governance of individual factors, including governance of the population's awareness of insurance participation and governance of the population's ability to participate in insurance; and (2) government factors, which included the degree of clarity of the government's governance function, the degree of medical insurance information sharing between regions, the degree of information technology construction in the medical insurance sector, the government's governance capacity, and the completeness of governance tools. The specific distribution of variables is shown in Table 1.

FIGURE 1
Trend of health insurance coverage in China from 2009 to the present. In 2013, due to the duplication of statistics on the number of participants in the New Rural Cooperative and urban medical insurance, the total number of people covered by the national medical insurance was high, and if duplicate statistics were excluded, the participation rate would still be above 95%.

Statistical analysis

Logistic regression model

Logistic regression is a generalized linear regression analysis that uses a logit function to fit data to predict the probability of an event occurring or to screen for joint markers or dependent variables, with the probability and independent variable model usually being an S-shaped curve. Since the dependent variables used in this study were binary (0 and 1), the binary logistic regression model, which is mainly used to describe an optimal mapping relationship between the independent variables and the response variables with dichotomous nature, was used. The expression of the logistic regression mathematical model was as follows (17–19):

$$logit\left\{y_i = y_1|X_i\right\} = logit\left(p_i\right) = \log\left[\frac{p_i}{1 - p_i}\right]$$
$$= \beta_0 + \beta_1 X_1 + \cdots + \beta_j X_j + \cdots + \beta_k X_k = \beta_0 + \beta' X_i,$$

where $p_i = probability\left\{y_i = y_1|X_i\right\}$, β_0 is the y intercept, β' is the vector of slope parameters, y_i is the first ordered level of y, and X_i is the vector of explanatory variables.

In the binary logistic regression equation above, the response variable was the log dominance ratio (log) for Y = 1. The meaning of the regression coefficient can be understood as the change in the log dominance ratio of the dependent variable that may be induced by a unit change in the independent variable, i.e., the parameter in the regression equation that indicates the magnitude of the effect of the independent variable on the dependent variable. As the logarithmic function is more convenient, faster, and easier to interpret, it was chosen as the model for statistical analysis in this study to determine the factors affecting the effectiveness of HIPC governance.

Data analysis

All statistical analyses were performed using SPSS 26.0, with confidence intervals at 95%, and bilateral statistical significance was based on a p-value of <0.05. In the first step, descriptive statistical analysis was used to describe participant characteristics and HIPC governance effects; in the second step, chi-square independence tests were used to analyze differences in categorical variables; and in the third step, multi-factor logistic regression analysis was performed to identify significant factors influencing HIPC governance effects and to control for possible confounding variables.

Results

The characteristics of the sample

Among the control variables, men accounted for 32.05%, and women for 67.95% of respondents; the respondents were all adults, with a majority aged 44 years and below (66.73%). The lowest level of education among the group was bachelor's degree (56.10%), indicating that the education level of the respondents was in line with the actual situation of the nine-year compulsory education implemented in China. Most of the survey respondents' majors were in medical insurance-related disciplines, accounting for 53.6% of respondents; their job types were mainly in the medical

TABLE 2 Sample characteristics and univariate analysis of the effect of governance on health insurance coverage for the entire population.

Variables	Total (N = 1,975)	Achieving the governance effect of universal health insurance coverage [n (%)]		X^2	P-value
		Bad	Good		
Governance of the population's awareness of insurance participation				13.950	0.000
Unrelated	1,047	385 (0.368)	662 (0.632)		
Related	928	418 (0.45)	510 (0.55)		
Governance of people's ability to participate in insurance				12.655	0.000
Unrelated	999	445 (0.445)	554 (0.555)		
Related	976	358 (0.367)	618 (0.633)		
Clarity of government's governance functions				8.460	0.004
Unclear	712	259 (0.364)	453 (0.636)		
Clarity	1,263	544 (0.431)	719 (0.569)		
The degree of medical insurance information sharing between regions				0.048	0.827
Not achieved	504	207 (0.411)	297 (0.589)		
Achieved	1,471	596 (0.405)	875 (0.595)		
The degree of information technology construction in the medical insurance sector				526.250	0.000
Low level	294	184 (0.626)	110 (0.374)		
General	730	483 (0.662)	247 (0.338)		
High level	951	136 (0.143)	815 (0.857)		
Government's governance capacity				606.249	0.000
Poor ability	146	105 (0.719)	41 (0.281)		
General	755	529 (0.701)	226 (0.299)		
High ability	1,074	169 (0.157)	905 (0.843)		
Governance tools completeness				221.768	0.000
Incomplete	666	323 (0.485)	343 (0.515)		
General	692	378 (0.546)	314 (0.454)		
Complete	617	102 (0.165)	515 (0.835)		

insurance sector, accounting for 81.1% of respondents, indicating that most of the survey respondents' job types were directly related to medical insurance.

Single-factor analysis of the governance effect of full population coverage of medical insurance

The results of the survey showed that 59% of the respondents had a good knowledge of the governance efficiency of the HIPC. The governance effect of HIPC and its influencing factors are detailed in Table 1. The HIPC had achieved remarkable results since the government began governing health insurance coverage for the entire population. Refer to Figure 1 for details.

Table 2 illustrates the estimation results controlling for individual background characteristics with government factors and governance of individual factors as the main explanatory variables.

The results showed that all individual factors have a significant effect ($p < 0.05$) on the effectiveness of HIPC governance, and all the governing factors are significantly associated with the efficacy of HIPC governance ($p < 0.05$), except for inter-regional health insurance information sharing. For details, refer to Table 2.

Multivariate logistic regression analysis of the governance effects of full population coverage of medical insurance

Based on the results of the single-factor analysis, this study assigned the statistically significant influencing factors and the effect of governance of China's health insurance coverage for the whole population in turn. The study substituted them into the logistic regression equation for multi-factor analysis; the results are shown in Table 3 in detail. The effect of targeting the governance of the population's ability to participate and the governance of

TABLE 3 The logistic regression analysis of factors influencing the effectiveness of governance for full population coverage of medical insurance ($n = 1,975$).

Variable	OR (95% CI)	P-value
Governance of the population's awareness of insurance participation	0.847 (0.677, 1.059)	0.145
Governance of people's ability to participate in insurance	1.516 (1.212, 1.897)	0.000
Clarity of government's governance functions	0.933 (0.738, 1.181)	0.565
The degree of information technology construction in the medical insurance sector	2.345 (1.973, 2.788)	0.000
Government's governance capacity	4.284 (3.490, 5.258)	0.000
Governance tools completeness	1.370 (1.182, 1.588)	0.000

TABLE 4 Classification results according to the explaining variable of the original data—logistic regression analysis ($n = 1,975$).

Variable	OR (95% CI)	P-value
Awareness of people's participation	0.835 (0.669, 1.044)	0.113
Crowd participation capacity	1.505 (1.204, 1.882)	0.000
Clarity of government's governance functions	0.940 (0.743, 1.189)	0.607
The degree of information technology construction in the medical insurance sector	2.088 (1.792, 2.432)	0.000
Government's governance capacity	3.598 (2.996, 4.320)	0.000
Governance tools completeness	1.288 (1.125, 1.474)	0.000

the health insurance coverage across the population is positively affected at a significant level of 5%. Other indicators positively affect the effect of governance of China's health insurance total population coverage, among which the degree of information construction of the health insurance sector, government's governance ability, and governance tools positively affect at a 5% significant level, that is, the higher the degree of information construction of health insurance sector, the higher the government's governance ability; and the more complete the governance tools and instruments, the better the effect of governance of China's health insurance total population coverage.

Sensitivity analysis

This study conducted a sensitivity analysis by changing the outcome classification of the independent or dependent variables, which may have an impact on the significant results of the explanatory variables. Therefore, in this study, the results of the independent variables were first set to 3 categories, i.e., 1 = not very effective (choice of "not at all effective" and "not very effective"), 2 = average (choice of "average") and 3 = effective (choice of "relatively effective" and "very effective"), the results of the explanatory variables were statistically analyzed according to the 3 categories, and the results of the adjusted model were

unchanged (Table 4). Subsequently, the independent variables were analyzed by the two classification results, the explanatory variables were analyzed by the five classification results of the original data, and the statistical steps were repeated. The adjusted model results were generally consistent with the statistical analysis of the previous data, again indicating that the results of this study were stable and reliable (Table 5).

Discussion

This study aimed to investigate the factors that influence the effectiveness of the governance of health insurance total population coverage. The results of the study showed that factors such as the governance of the population's ability to participate in insurance, the degree of information technology construction in the medical insurance sector, government's governance capacity, and governance tools completeness significantly affect the effectiveness of the governance of health insurance coverage for the whole population.

This study found that governance of the population's ability to participate in insurance was positively correlated with the impact of achieving governance effectiveness in HIPC. Studies have shown that nearly half of China's uninsured population is uninsured due to their low participation ability. This group offers a high willingness to participate, resulting in an unbalanced phenomenon of high demand for health insurance and adverse selection of actual participation [20–22]. Studies have shown that, in other countries, the uninsured are more likely to be uninsured due to their low capacity to participate [23, 24]. China noticed this phenomenon early in the process of HIPC promotion and has enhanced the public's ability to participate in health insurance, especially for the poor, through diversified means such as health insurance poverty alleviation policies, medical assistance underwriting policies, and continuous lowering of health insurance contribution thresholds, effectively bringing people with low participation ability into the scope of health insurance, making China's HIPC governance achieve good results [21, 25]. According to official data, since China launched medical insurance to help the poor and established a multi-level medical insurance system, 230 million people in poverty have been insured, and the coverage of the poor has stabilized at over 99.9% [26]. Therefore, China should adhere to the policy guidelines such as "health insurance for the poor" and continue the evolution of the governance measures for the population's ability to participate in the insurance and continue to consolidate the achievements of "universal health insurance, Everyone who can be guaranteed is guaranteed" in China.

Second, the degree of information technology construction in the medical insurance sector significantly impacts the effectiveness of achieving full population coverage of medical insurance governance. Tomasz Janowski's research also shows that the development of information technology and digitalization affects governance goals [27]. Countries such as Brazil have effectively promoted HIPC by adopting a unified medical insurance information system platform [28]. Currently, China's medical insurance information technology is in its infancy. The medical insurance information system cannot share information with other related departments, making it difficult to effectively and timely

TABLE 5 Analysis of results classified according to explaining variable 3—logistic regression analysis (*n* = 1,975).

Variable	Inefficient		General	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Governance of the population's awareness of insurance participation				
Unrelated	0.815 (0.508, 1.307)	0.396	0.841 (0.659, 1.074)	0.166
Related (reference)				
Governance of people's ability to participate in insurance				
Unrelated	1.212 (0.752, 1.955)	0.430	1.598 (1.248, 2.045)	0.000
Related (reference)				
Clarity of government's governance functions				
Unclear	0.581 (0.345, 0.981)	0.042	0.971 (0.753, 1.253)	0.823
Clarity (reference)				
The degree of medical insurance information sharing between regions				
Not achieved	2.482 (1.490, 4.133)	0.000	1.101 (0.828, 1.463)	0.510
Achieved (reference)				
The degree of information technology construction in the medical insurance sector				
Low level	12.558 (6.416, 4.579)	0.000	2.526 (1.731, 3.685)	0.000
General	3.086 (1.523, 6.254)	0.002	4.972 (3.734, 6.621)	0.000
High level (reference)				
Government's governance capacity				
Poor ability	11.054 (5.630, 1.704)	0.000	4.076 (2.478, 6.702)	0.000
General	2.452 (1.336, 4.499)	0.004	5.448 (4.167, 7.124)	0.000
High ability (reference)				
Governance tools completeness				
Incomplete	2.014 (1.027, 3.950)	0.042	2.139 (1.526, 2.999)	0.000
General	1.477 (0.710, 3.073)	0.297	2.567 (1.840, 3.582)	0.000
Complete (reference)				

screen uninsured people and bring them into the medical insurance coverage from a technical level (29–31). Meanwhile, medical insurance information systems are usually oriented toward regional health insurance services (31), and there are barriers to information systems between different medical insurance systems. This results in the inability to share information on public participation, the increased probability of biased targeting of uninsured people by health insurance departments, and the increased difficulty of full population coverage of medical insurance, which in turn affects the effectiveness of the governance of full population coverage of medical insurance in the country. Therefore, China should hasten the construction of a unified national health insurance information platform, break the barriers between regional health insurance information systems, actively promote the integration and docking of health insurance information systems with information systems of other relevant departments, rely on blockchain and other technologies to achieve inter-regional and inter-departmental sharing of insurance information, establish an identification system for uninsured people, and achieve accurate targeting of uninsured people through big data matching and other means.

Our findings showed that the size of the government's governance capacity and the completeness of its governance tools directly correlates with the effectiveness of the governance of the whole population coverage of health insurance in China. Studies by related scholars also emphasize that the government's governance capacity and the completeness of governance tools are paramount to enhancing the effectiveness of HIPC governance (32–34). Relevant studies have shown that governance in the public sphere, central government institutions, and governance capacity are critical prerequisites for effective governance (35). China has also gradually recognized this in HIPC governance and established the National Health Insurance Administration in 2018 to strengthen the top-level design of HIPC and rationalize the health insurance management system. The former Health and Planning Commission was responsible for the new agricultural cooperation. The former Ministry of Human Resources and Social Security was responsible for the medical insurance of urban residents and urban workers; three kinds of medical security were unified under the management of the Medical Insurance Bureau. From an institutional perspective, it solved the long-standing state

of HIPC governance of nine dragons, effectively circumvented the dead ends in HIPC governance, and provided a solid and robust organizational guarantee for HIPC governance in China. In addition, China also provided a good platform and legal support for HIPC governance in China by building a medical insurance information and business coding platform, continuously improving its medical insurance legal system and other diversified governance tools. Its efforts in augmenting its governance capacity and governance tools have effectively alleviated China's HIPC governance dilemma and laid a solid foundation for it to achieve more effective HIPC governance. In recent years, the new pneumonia epidemic has accelerated the process of building digital health insurance in China. In addition, the integration of modern information technology such as blockchain, the Internet of Things, and big data with the health insurance governance system has become the mainstream trend to enhance governance capacity and improve governance tools in China. However, it is still in its initial stage of development and needs to be explored to enhance digital governance capacity and improve digital governance tools. Therefore, China should continue to strengthen its macro system construction and planning, plan for the development of governance capacity and tools, respond positively to the needs of HIPC governance, build a digital governance network for health insurance, strengthen modern information technology, and provide strong institutional and technical support for the development of health insurance governance capacity and tools.

Conclusions

In this study's survey, 59% of respondents believe that HIPC governance is effective. China has effectively solved the problem of low-participation ability and people's participation through medical insurance poverty alleviation, medical assistance underwriting policy, and lowering the threshold of medical insurance payment. It has also actualized the precise expansion of medical insurance coverage for the uninsured, resulting in its HIPC governance achieving good results. In addition, in realizing HIPC governance, accelerating the construction of health insurance information systems, promoting the modernization of governance capacity, and expanding good governance tools that can effectively promote the accurate expansion of health insurance population coverage, which is an effective path to realizing efficient HIPC governance.

Limitations

Although this study contributes to the understanding of HIPC governance in China and the factors influencing it, there are still some limitations that need to be noted. China's HIPC governance is the focus of China's current healthcare development, and it has gradually entered a period of rapid development with the continuous improvement of the healthcare governance system, and because the data used in this study is a cross-sectional study for the whole country, it cannot show a longitudinal analysis of the effectiveness of China's health care governance; therefore, the findings of this study may show certain stage characteristics.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: The datasets generated during and/or analyzed during the current study are not publicly available due to protection of privacy of respondents, but are available from the corresponding author on reasonable request. Requests to access these datasets should be directed to kangzheng@hrbmu.edu.cn.

Ethics statement

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

Author contributions

TZ and WM conducted and planned the study and designed the methodology. TZ and HZ drafted the manuscript. TZ and JX conducted a feasibility analysis and helped conceptualize the project. QS and JL conducted the literature search and data visualization. FD and JH proofread and revised the article's language. FC and ZK revised the manuscript and gave critical feedback. ZK and GT conducted quality control and review of the manuscripts. TZ, WM, HZ, and JX contributed to the concept, design, research, data analysis, and drafting of the article. All authors have read and approved the manuscript 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.

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The associations between working conditions and subjective sleep quality among female migrant care workers

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Background: Subjective sleep quality may reflect the mental well-being of migrant care workers; however, the related occupational factors remain unclear. This study examines the association between the characteristics of care labor and the subjective sleep quality of female migrants.

Methods: In this cross-sectional study, Southeast Asian migrant care workers in Taiwan were recruited using convenience sampling. Data on working conditions, including workplace setting, wage, working hours, psychiatric symptoms of care recipients, and sleep quality measured using the Pittsburgh Sleep Quality Index (PSQI), were collected through computer-assisted personal interviews. Multiple linear regression analyses were performed to determine the independent relationship between working conditions and the PSQI global score.

Results: There were 220 institution-(47.7%) and home-based (52.3%) care workers, and 47.7% had a PSQI score higher than 5. After controlling for covariates, the lowest tertile of wages and daily working hours (>8h) were independently correlated with poor sleep quality. Moreover, in the stepwise regression model, wage and working hours remained the most explainable correlates of poor sleep quality.

Conclusion: This study lent support to the notion that low wages and long working hours are significant occupational factors that negatively impact the subjective sleep quality of female Southeast Asian migrant care workers in Taiwan.

KEYWORDS

migrant, care worker, sleep quality, working conditions, minority

1. Introduction

Demand for eldercare is expanding in many post-industrial countries (1). However, the long-term care sector has been haunted by labor shortages due to persistent structural problems, including understaffing, job insecurity, and complex skill demands without sufficient training (1). The unsatisfactory compensation, arduous workload, and devalued social position, resulted

in difficult recruitment and low retention rate of long-term care workers; most modern societies rely on minorities, such as female migrants, to sustain the need for long-term care in their aging populations (2–4).

However, although a wide gap existed in the working conditions between migrants and native care workers (5, 6), the mental health consequences for these migrant care workers were rarely acknowledged by academic work. The lack of conclusive evidence regarding mental well-being among migrant care workers may be due to inadequate research methodologies. Although in-depth interviews have revealed that migrant care workers constantly feel tense at work (4, 7), quantitative studies have shown no or only mild psychological stress (6, 8). These results might underestimate the mental distress among migrant care workers, since they might be reluctant to disclose their psychological suffering for fear of employer retaliation or risk of deportation (7). Moreover, conventional in-person surveys conducted among immigrant populations tended to be biased by social desirability and language barriers (9). To overcome the limitations of conventional survey methods, the use of computer-assisted personal interviews (CAPI) could improve the reliability of survey results. Such survey methods could also protect privacy and increase participant autonomy for sensitive issues, such as mental disorders, sexual behaviors, and HIV infection (10–12). To the best of our knowledge, no study has utilized CAPI to facilitate mental health research in migrant care workers.

Instead of methodological improvements, some studies used sleep duration as a proxy for the mental well-being of migrant care workers, which was less confidential than other psychiatric measurements (8, 9, 13). Nonetheless, some migrant care workers reported unsatisfactory sleep quality despite having a subjective normal length of sleep (8). It was challenging to accurately assess the total length of their fragmented sleep, especially for home-based care workers who provide round-the-clock services. In contrast, self-reported sleep quality had a higher predictive power than sleep quantity for physical and psychiatric comorbidities (14–16). Subjective sleep quality also mediates a larger proportion of the relationship between structural adversities and health than does sleep duration (17). Therefore, sleep quality may be more informative than sleep duration in the psychosocial context of migrant care workers.

Jackson et al. (18) examined racial disparities in sleep among various kinds of occupations and suggested that structural inequities in the workplace influenced sleep between immigrants and native workers. In the healthcare industry, low socioeconomic status, long working hours, and frequent night shifts were predictors of differences in sleep duration between African or Caribbean immigrants and Native White employees (19). These studies revealed that occupational factors played a pivotal role in the racial disparity in sleep, and that understanding occupational determinants of sleep could be imperative to promote the mental health of migrant care workers. Nevertheless, the exact work-related factors that affect subjective sleep quality remain unclear.

In this study, we recruited Southeast Asian female migrant care workers in Taiwan and collected data using mobile-based in-person surveys. This study aimed to investigate the correlation between working conditions and subjective sleep quality. We hypothesized that disadvantaged working conditions, including low wages, extended work hours, and increased psychiatric symptoms in care recipients, would be associated with poor subjective sleep quality among migrant care workers.

2. Methods

2.1. Study participants

The global care workers' labor market is highly gender-segregated and female-predominant (20). There were 219,295 migrant workers in the social welfare sector of Taiwan in May 2022, but over 99% of them were female from nearby Southeast Asian countries (21). Therefore, only females were recruited in this cross-sectional study. Migrant care workers who were above 18 years of age, whose country of origin was Indonesia, Vietnam, or the Philippines, and who had been working in Taiwan as in-home care workers or employees of nursing or residential institutions were eligible. In addition, the participants required English or Chinese fluency and the ability to read questionnaires written in English, Chinese, Indonesian, or Vietnamese. Eligible participants were recruited using convenience sampling between January 2021 and November 2021. All participants were introduced to the research assistants through the agency leaders and a non-profit organization for migrant workers. The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2008. Written informed consent was obtained from all study participants. This study was approved by the institutional review board of the National Taiwan University Hospital (number 201912142RINB).

2.2. Data collection

Data were collected through CAPI, using the Qualtrics online survey platform. All the structured questionnaires used in this study validated the Indonesian and Vietnamese versions. We commissioned two professional translation services to translate the remaining survey content into Indonesian and Vietnamese and asked both parties to reconcile any translation inconsistencies to reach a consensus. This version was then read by Indonesian and Vietnamese people from a non-profit organization who were familiar with both cultures and languages to ensure that the final version was semantically accurate.

The participants either used their own smartphones or tablet computers provided by the researchers to complete the survey. During the interview process, participants were always able to contact nearby research assistants if they had any questions regarding the online questionnaires. Respondents who were interrupted by their duties could finish the survey later on that day during their available time since the Qualtrics platform allowed for temporary storage and asynchronous messaging.

2.3. Variables of working conditions

Based on previous studies targeting medical professionals and caregivers, factors contributing to poor sleep quality include wages (22),

working hours (13), psychiatric symptoms of the care recipient (23–25), subjective stress from nursing work (23, 26), and depression (25). Therefore, in addition to basic sociodemographic data (age, sex, nationality, and educational attainment in years), our online survey inquired about participants' psychiatric history (presence vs. absence); work conditions, including workplace setting (private residence vs. nursing institution); monthly wage (lowest tertile vs. upper and middle tertiles); and daily working hours (>8 vs. ≤8). The literature suggests that the relationship between income and sleep quality could be non-linear (27, 28); thus, we defined the lowest tertile as the "case" for low income. In addition, psychiatric symptoms in care recipients, psychological distress, and subjective sleep quality were evaluated. Individuals were asked to report whether their care recipients had sleep disturbances; difficulties in communication; hallucinations or delusions; and hostility toward caregivers, namely, being verbally and/or physically aggressive. The respondents answered each question with either yes or no. The number of symptoms manifested was summed as a continuous variable.

2.4. Psychological distress

Participants completed the Patient Health Questionnare-9 (PHQ-9) in the version of their acquainted language to measure emotional distress. The PHQ-9 is a self-administered questionnaire that can be completed in approximately 3 min. It is used worldwide to screen for and assess depression severity. A higher PHQ-9 score indicates a higher severity of psychological distress within the past 2 weeks. The questionnaire is applicable in general primary care settings, demonstrating high reliability and validity, and is available in Chinese, English, Indonesian, and Vietnamese languages (29–32). The PHQ-9 consists of nine questions, of which the most significant ones can be used as references for the diagnosis of depression in the DSM-5. The summed score from the nine questions also reflects depression severity.

2.5. Self-reported sleep quality

We used the Pittsburgh Sleep Quality Index (PSQI) to assess the sleep quality of the study participants within the past month (33). The PSQI is a self-administered questionnaire that takes approximately 5–10 min to complete. It comprises 19 questions that assess seven domains pertaining to sleep: subjective sleep quality, sleep onset latency, total sleep duration, sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. A lower PSQI score indicates better sleep quality in the past month. The PSQI has been translated into multiple languages, including Indonesian, Chinese, Vietnamese, and English, all of which have high reliability and validity (33–36). Using a PSQI total score >5 to distinguish poor sleepers from good sleepers yielded satisfactory sensitivity and specificity. In the present study, total component scores were used to reflect the subject's sleep quality.

2.6. Statistical analysis

Statistical analyses were performed using Microsoft Excel 2019 and SPSS version 17.0 (SPSS Inc., Chicago, IL, United States).

Descriptive statistics are presented as the mean ± SD for continuous variables and n (%) for categorical variables. We conducted a Pearson correlation analysis to assess the correlations between continuous independent variables and the total PSQI score. The t-test and analysis of variance (ANOVA) were used for univariate analysis of categorical predictors. All predictors were then subjected to multiple regression analysis with forced entry and stepwise entry methods to examine their independent effects on PSQI. Results yielding a value of $p < 0.05$ were considered statistically significant.

3. Results

A total of 220 migrant care workers of Vietnamese (24.5%), Indonesian (63.2%), and Filipino (12.3%) nationalities participated in this study. Table 1 shows the main sociodemographic and employment conditions of the migrant workers. The average age of the participants was 36.3 ± 7.4 years (range = 21–68), with an average educational

TABLE 1 Sociodemographic and clinical characteristics of participants (n=220).*

	Total (n=220)
	n (%)
Age (years; mean, SD)	36.3 ± 7.4
Education (years; mean, SD)	11.2 ± 2.5
Nationality	
Vietnam	54 (24.5)
Indonesia	139 (63.2)
Philippines	27 (12.3)
Psychiatric history	
No	209 (95.0)
Yes	11 (5.0)
Workplace setting	
Nursing institution	105 (47.7)
Home	115 (52.3)
Wage (thousand, NTD; mean, SD)	
Upper two tertiles	21.1 (2.61)
Lowest tertile	17.0 (0.44)
Daily workhour	
≤8	48 (21.8)
>8	169 (76.8)
Number of psychiatric symptoms of care recipient (mean, SD)	2.1 ± 1.7
Subjective stress from care work	
No	78 (35.5)
Yes	142 (64.5)
Patient Health Questionnaire-9 (mean, SD)	3.9 ± 4.3
Pittsburgh Sleep Quality Index (mean, SD)	5.5 ± 3.3

*Numbers of subjects do not equal because of missing values in variables.

TABLE 2 Correlation matrix between age, education, number of psychiatric symptoms of care recipients, Patient Health Questionnaire, and Pittsburgh Sleep Quality Index.

		1	2	3	4	5
1	Age (years)	1				
2	Education (years)	−0.15*	1			
3	Number of psychiatric symptoms of care recipients	0.11	−0.01	1		
4	Patient Health Questionnaire-9	−0.27**	−0.04	0.22**	1	
5	Pittsburgh Sleep Quality Index	−0.16*	0.01	0.05	0.61**	1

*Value of $p < 0.05$, **value of $p < 0.01$.

TABLE 3 Univariate analyses for factors associated with Pittsburgh Sleep Quality Index.

	Pittsburgh Sleep Quality Index	
	mean±SD	Value of p for t test/ANOVA
Nationality		
Vietnam	3.91 ± 3.03	
Indonesia	6.13 ± 3.31	<0.001
Philippines	5.78 ± 3.03	
Psychiatric history		
No	5.52 ± 3.33	
Yes	6.00 ± 3.55	0.67
Workplace		
Nursing institution	4.81 ± 3.35	
Home	6.21 ± 3.20	0.002
Wage		
Upper two tertiles	5.13 ± 3.26	
Lowest tertile	6.58 ± 3.33	0.004
Daily workhour		
≤8	4.90 ± 3.33	
>8	5.74 ± 3.32	0.12
Subjective stress from care work		
No	4.68 ± 3.49	
Yes	6.02 ± 3.16	0.004

attainment of 11.2 (±2.5) years. Five percent of participants had a psychiatric history. Of the participants, 47.7% worked at nursing institutions, while 52.3% worked as private family caregivers. Migrant caregivers had salaries that ranged between $16,000–25,000 NTD at the time of interview, with an average of $19,923.2 (±2,901.9) NTD (=$667.8 ± 97.3 USD). The average wage of the lowest tertile was $16,972.2 NTD (±438.0), whereas that of the middle and upper tertiles was $21,107.1 NTD (±2,611.4). Migrant caregivers worked for 11.8 (±4.5) hours per day, and 76.8% of them worked for over 8 h per day. Their care recipients had 2.1 (±1.7) psychiatric symptoms in average. Overall, 64.5% of the participants considered their caregiving work to be highly stressful. In terms of mood- and sleep-related factors, the average PHQ-9 score was 3.9 (±4.3). The average PSQI global score was 5.5 (±3.3), with 47.7% of the participants ($n = 105$) scoring higher than 5.

Table 2 shows the correlations between the PSQI total score and continuous independent variables. The global PSQI score was negatively correlated with age ($r = −0.16$, $p < 0.05$) but positively correlated with the PHQ-9 score ($r = 0.61$, $p < 0.01$). Education and the number of psychiatric symptoms in care recipients were not significantly associated with the PSQI score.

As presented in Table 3, univariate analyses of categorical predictors showed that psychiatric history and daily working hours were not associated with the PSQI scores. However, significant between-group differences in sleep quality were found based on nationality ($p < 0.001$), workplace setting ($p = 0.002$), wage ($p = 0.004$), and subjective stress from care work ($p = 0.004$).

In Table 4, the multiple linear regression analysis shows an independent relationship between various working conditions and subjective sleep quality. We examined the collinearity statistics for our multiple linear regression model and found that the range of Variance Inflation Factor was 1.05–2.91, indicating a low to moderate degree of collinearity among the independent variables. After controlling for covariates, the association between workplace and subjective stress from care work and higher PSQI scores vanished. By contrast, participants within the lowest tertile of wages had a higher PSQI than those in the other two tertiles [B(se) = 0.83(0.41), $p = 0.046$]. Working for more than 8 h per day proved to be associated with a higher PSQI compared to the counterpart [B(se) = 1.01(0.44), $p = 0.02$]. Stepwise regression analysis was used to identify the most explainable associates of working conditions. Low income, long working hours, and high PHQ-9 scores appear to be robust risk indicators for poor sleep quality.

4. Discussion

Using CAPI, the present study examined the determinants of working conditions for subjective sleep quality in female migrant care workers in Taiwan. The findings indicate a high prevalence of poor sleep quality among migrant care workers. After partialling out rigorous confounding effects, lower wages and longer working hours turned out to be independently associated with poor sleep quality among various working conditions. To the best of our knowledge, this is the first study to specifically elucidate the link between disadvantaged employment conditions and subjective sleep quality among migrant care workers. Moreover, CAPI substantially reduces information bias and promotes information accessibility, making this study stand out.

TABLE 4 Multiple linear regression analyses for factors associated with Pittsburgh Sleep Quality Index.

	Pittsburgh Sleep Quality Index						
	Full model				Stepwise		
	B (se)	95% CI	Value of *p*		B (se)	95% CI	Value of *p*
Age (years)	0.02 (0.03)	(−0.03, 0.08)	0.36				
Education (years)	−0.05 (0.09)	(−0.22, 0.13)	0.62				
Nationality							
Indonesia vs. Vietnam	0.64 (0.63)	(−0.59, 1.87)	0.30				
Philippines vs. Vietnam	1.73 (0.75)	(0.25, 3.20)	0.02				
Psychiatric history							
Yes vs. No	0.25 (0.82)	(−1.37, 1.87)	0.76				
Workplace							
Home vs. Nursing institution	0.28 (0.50)	(−0.71, 1.28)	0.57				
Wage							
Lowest tertile vs. Upper two tertiles	0.83 (0.41)	(0.02, 1.64)	0.046	2	1.05 (0.40)	(0.26, 1.83)	0.01
Daily workhour							
>8 vs. ≤8	1.01 (0.44)	(0.15, 1.88)	0.02	3	0.86 (0.43)	(0.02, 1.70)	0.046
Number of psychiatric symptoms of care recipient (mean, SD)	−0.20 (0.13)	(−0.46, 0.05)	0.12				
Subjective stress from care work							
Yes vs. No	0.62 (0.43)	(−0.23, 1.47)	0.15				
Patient Health Questionnaire-9	0.46 (0.05)	(0.36, 0.55)	<0.001	1	0.46 (0.04)	(0.38, 0.54)	<0.001

4.1. Computer-assisted personal interviews enhances accessibility and validity of information

Although abundant literature has focused on the mental health condition of migrant care workers or compared their mental distress with that of native workers, the results were mixed (4, 6–8, 37–39). Methodological difference was one of the main attributes, in which anticipated rejection of psychiatric disabilities, linguistic unproficiency, and time deficiency were major challenges for studies in migrant workers (40, 41). Specifically, migrant workers were afraid of mental health stigmas that would prevent them from keeping their jobs, and some employers would warn respondents to not damage their reputations (9). As a result, interviewers tended to respond in a positive way during traditional interviews to make the process more welcoming. In the present study, potential biases were minimized by using an online survey platform that allowed for anonymous login to protect the privacy of the participants' responses and enabled temporary storage and offline use to save the precious time of migrant care workers. Another strength of CAPI lies in its language flexibility. For example, online questionnaires could include as many as 16 languages in a study conducted in a region of high ethnic diversity (11). Reduction of language barriers could facilitate genuine responses that reflect their mental well-being.

4.2. High prevalence of poor sleep quality in migrant care workers

Approximately half of the migrant care workers in our study reported poor sleep quality. Previous research found that the sleep duration of migrants was shorter than that of native workers in the healthcare industry (18, 19), but direct comparisons of subjective sleep quality between migrant and native workers are lacking. In Germany, Korea, and Taiwan, the prevalence of poor sleep quality evaluated by the PSQI ranged from 30.3 to 40.9% among working populations (42–44). Although convenience sampling might have affected the estimation of the prevalence of poor sleep quality in this study, we attempted to increase the diversity of our community samples by recruiting volunteers from different sources, such as nursing agencies and non-governmental organizations. Compared to the statistics for the general public, migrant care workers reported a relatively high proportion of poor sleep quality. It is possible that occupation had a negative influence on mental well-being, in addition to pre-existing disadvantages in ethnicity and sex.

4.3. Working conditions and sleep quality

While many studies have examined racial disparities in health and gender segregation in the labor market, only a few have investigated

the occupational health of migrant care workers (6, 37, 38). These works confined their focus on some aspects of care labors, such as job precarity, job strain, and COVID-19 pandemic. In contrast, in this study, we considered a set of more comprehensive variables for working conditions. In addition to wages (22) and working hours (13), psychiatric symptoms of the care recipient (23–25) and subjective stress from nursing work (23, 26) were also specified in the regression models because they were established risk indicators for medical professionals as well as caregivers, whereby migrant care workers also featured. We found that workplace setting, wages, and subjective stress from care labor had significant crude associations with sleep quality, but only wages remained in the adjusted model. In contrast, working hours were associated with poor sleep quality until the adjustment for confounders. Furthermore, the results of stepwise linear regression also ascertained wage and working hours as the most explanatory variables for sleep quality in migrant care workers. Compared with the workplace and subjective stress, wages and working hours are more subject to labor law regulations. Accordingly, our findings demonstrate the imperativeness of including comprehensive indicators of working conditions when researchers intend to identify pivotal and modifiable factors that promote laborers' health.

This study showed that lower income was associated with worse subjective sleep quality. This result was consistent with surveys conducted among the general public, in which living in poverty caused problematic sleep (45). There may be a bidirectional relationship between poverty and poor sleep quality. In our study, participants were in similar socioeconomic status; thus, theory of "social causation" is preferred to "social drift" as the mechanism that underlie our findings. Although migrant workers in Taiwan may already have higher earnings than they have in their home countries, the "relatively low" incomes, indicated as the lowest tertile among participants in this study, may remain to incur feeling of "relative deprivation." Evidence that workers who perceived their wages as unfair would report higher sleep dissatisfaction also supports our contention (22). Whether reducing income inequality or elevating basic income would benefit the mental health of migrant care workers needs further research.

Three-quarters of the participants in this study worked more than 8 h per day. Working for extended hours with unstable work schedules is a global phenomenon among migrant care workers (46, 47). While non-shift workers have been found to have an elevated risk of insomnia with prolonged day time working hours (48), the situation could be worse for live-in care workers who must adapt to irregular split-schedule sleep (9, 46). Notably, in this study, working hours were found to exhibit an adverse impact on sleep quality only in the adjusted model. From a statistical perspective, the deleterious effect of extended working hours on sleep quality may be neutralized by protective confounders in unadjusted analyses. Further investigations are warranted to examine protective factors, such as sleep hygiene behaviors or sleep–wake schedules, in workers with long working hours.

4.4. Psychometric properties of the PSQI-defined sleep quality

Existing research on the sleep health of migrant care workers has mostly focused on sleep duration or objective measurement of sleep quality (18, 19), but little is known about their subjective sleep quality. While subjective and objective measures of sleep quality have only modest correlations, their implications for mental health also differ (49). Compared with objective estimates of sleep quality, the extent to which subjective sleep quality (i.e., PSQI-defined sleep quality) correlates with mental health is greater (49, 50). Thus, the construct potentially shared between the PSQI and mental distress contrasted the robust roles of low wage and long working hours as predictors for poor sleep quality under the strong explanatory power from depression.

4.5. Limitations

A few limitations of this study should be considered when interpreting our results. First, causal inferences were not possible in this cross-sectional study. However, the key determinants of working conditions for sleep quality identified in this study, wage and working hours, were less likely the consequences, but should have preceded sleep quality. Second, because the participants of this study included only women, the generalizability of the main findings to male migrant workers is limited. Additionally, our participants were migrants who worked in long-term nursing facilities and private residences. The majority of our in-home caregivers were recruited from a non-profit organization, the largest learning community for Southeast Asian migrant workers in Taiwan. These participants had joined classes aimed at empowering migrant workers through practical knowledge and skills that they might actually represent the healthier subgroup of in-home care workers. This selection bias may mask the disadvantages of in-home work settings. Finally, the PHQ-9 was used to control for confounding effects of depression. However, one of the items in the PHQ-9 that measured night insomnia symptoms and sleep duration was similar to some measures in the PSQI. Thus, specifying the PHQ-9 in statistical models may incur concern for over-adjustment. However, subjective sleep quality is a global impression of overall sleep–wake health, which indicates a higher scope and different dimensions when compared to night insomnia symptoms and sleep duration (49, 50). Even under these circumstances, lower wages and longer working hours remained risk indicators for poor sleep quality, which further highlighted the significance of these two indicators.

5. Conclusion

While migrant care workers are filling the gap in the healthcare workforce in many rapidly aging societies, it is mandatory to improve the working conditions for migrant laborers. According to our findings, the regularization of wages and working hours may be essential to enhance the mental well-being of migrant care workers. In the future, an in-depth exploration of factors that underlie the link between wages and working hours with subjective sleep quality with more representative individuals is warranted.

Data availability statement

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

Ethics statement

Author contributions

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Conflict of interest

Publisher's note

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Thoughts on the construction of public health informatization for community health archives grass roots management system

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With the development of social economy and the continuous improvement of people's living standards, people expect to receive high-level medical services, and the requirements for medical care are also getting higher and higher. However, there are still objective problems such as rising medical costs, difficulty in seeking medical treatment, uneven distribution of medical resources, low efficiency of medical services, and uneven medical quality. This paper first analyzes the significance of public health informatization construction, focuses on the elements of public health informatization construction, and expounds the status quo of health informatization construction and the existing problems in community health informatization. Then, this paper expounds the construction of public health informatization based on the grass-roots management system of community health records, and discusses the construction of a health information platform centered on the health records of community residents. Afterwards, this paper proposes and studies the functions of the community medical information archives management system from three aspects: the composition of the community medical information archives management system, the problems of system management, and the development requirements of the system, and proposes an algorithm based on a decision tree model to enhance public health informology. Finally, on the basis of experiments and investigations, Internet technology and decision tree model algorithms are introduced into the public health information system construction of the community health archives system to build a new public health information system, and the satisfaction rate can be increased by 23%.

KEYWORDS

public health information, community health records, grassroots management system, information construction, grass roots

1. Introduction

Scientific and orderly management is essential for the normal operation of community health services. In recent years, information management system plays an increasingly essential role in the health field. This is especially true for large and medium-sized hospitals. In these community health service institutions, health record management is gradually becoming computerized. By establishing a regional health information platform and realizing good interaction between health institutions, the overlapping of investment and construction costs in the health sector can

be reduced. The construction of an efficient and unified medical resource platform can achieve safe cooperation and profit growth, and effectively enhance the quality of medical services and the service level of medical institutions. This provides people with safe, efficient and affordable public health and basic health services, and effectively solve medical consultation problems.

Grass roots management system is widely used in public health information. Naeem Salman Bin believed that the scale of the crisis and the prevalence of misleading information required scientists, health information professionals and journalists to fulfill their professional responsibilities and help the public identify fake news reports [1]. Alsan [2] research found that there was a positive correlation between health protection behaviors and the use of broadcast media as information sources. When used as an information source, unregulated social media might bring health risks, which could be partly but not completely attributed to its role as a propagator of health related conspiracy beliefs. Finney Rutten assessed the progress of health communication and health information technology goals for healthy people in 2020. The goal was to increase the proportion of health information seekers who could easily access health information online [3]. Van der Meer [4] conducted an online experiment with samples in order to determine corrective information strategies to raise awareness and trigger actions during the outbreak of infectious diseases. The observed mediation of crisis emotion revealed the mechanism of correcting the influence of information. These findings provided a formula for the study of misinformation to correct the growing spread of misinformation in times of crisis. Sun [5] investigated the current use of the official WeChat account of the Centers for Disease Control and Prevention in public health education, as well as related factors that may affect the effect of information transmission, and carried out a retrospective investigation on the effectiveness of the official account. Jaks Rebecca studied parents' views on the Internet as a resource for improving health-related knowledge. The information seeking behavior, the type of digital media used, and the reason for use were analyzed descriptively [6]. Burr [7] research found that common mental health disorders were on the rise worldwide, which brought pressure to the public health system, and renewed people's interest in the possible role of digital technology in improving mental health outcomes. The above studies all described the application of public health information, but there are still some deficiencies in community health records.

Many scholars have analyzed and studied community health records. Trevisi [8] studied the impact of community outreach and patient empowerment interventions on the clinical outcomes of diabetes patients. The interventions were aimed at supporting community health development. Abu-Husn [9] reviewed the progress of health information digitization and the proliferation of health system genome research, and provided insights on a new path for the extensive implementation of personalized medicine. The purpose of Petts Rachel A study was to examine the comprehensive behavioral health care experience of patients and providers in health centers. He completed a survey on nursing satisfaction and the degree of integration of the clinic for two patients and providers using a mixed approach design [10]. Leis [11] found that in order to improve the influence of antimicrobial management in the community medical environment, the Public Health Bureau had carried out a key activity called the wise use of antibiotics. This campaign was led by antibiotic prescribers themselves, who worked in a community health care environment and were more able to identify specific changes that

support more appropriate use of antibiotics. Koleck [12] aimed to synthesize literature on the use of processing or analyzing symptom information recorded in text narratives. Valik [13] aimed to use electronic health record data to develop and verify the fully automatic monitoring system based on in non intensive care units. He proved its practicability by determining the burden of hospital sepsis and the differences between wards. Bellas [14] survey found that community health workers in developing countries often provided door-to-door services in degraded and violent areas. Therefore, he studied the impact of urban violence on performance in underdeveloped areas to understand the challenges of providing care to dangerous communities in developing countries. The above studies have all described the importance of community health records, but there are still some deficiencies in public health information.

In the face of objective problems, health care reform has been accelerated to enhance the level of health management. Unified standards are built to standardize the structure. The construction of a safe and reliable comprehensive medical information platform has become the consensus of the health sector, which takes residents' health records as the core to build, so as to cover a wide range of network services. This has greatly improved the quality and efficiency of work processing, and is conducive to providing intelligent and professional medical services for the society [15]. The government should serve the society and the people to ensure the long-term health development of health care for the benefit of the people and to win the hearts and minds of the government to develop health. To solve these problems, it is necessary to establish a regional information exchange platform centered on residents' health records to maximize the exchange of medical information and conduct regional information exchange among medical enterprises. Through vertical and horizontal integration, the overall level of health management is improved to achieve a higher level of service. Therefore, the regional health information platform is established to accelerate the growth of medical informatics and provide high-quality medical services. Efficient and intelligent medical services have become an inevitable trend of society [16].

2. Importance of public health information construction

2.1. Elements of public health information construction

Informatization is the main trend of world economic and social development. Information technology innovation is used to improve work efficiency. The success of medical reform is to build a house on the basis of four beams and eight columns. The first is to enhance the comprehensive development of public health. The second is to further improve the medical security system. The third is to speed up the construction of the medical security system. The fourth is to establish and enhance the drug supply security system. The eight pillars are to establish a unified health management system, an effective mechanism to supervise health institutions, and various health investment systems. The fourth is to establish a scientific and reasonable pricing mechanism for medical care. The fifth is to establish a strict and effective health monitoring system. The sixth is to establish a sustainable innovation mechanism to protect health science and technology talents. The

seventh is to construct a comprehensive and universal medical information system. The eighth is to establish and improve the right to health. In short, the four and eight pillars are the public health system, the medical insurance system and drug production. Computerization is the key to everything, and the development of medical information is undoubtedly the most important reform. The introduction of information technology can significantly reduce the cost of various communication and information transmission chains and greatly increase the quality of medical services (17).

2.2. Current situation of health information construction

The active promotion of informatization is a strategic measure for the overall modernization drive, which is an urgent need to realize the scientific outlook on development, and build a well-off society in an all-round way, a harmonious society and an innovative country. Informatization in the medical and health field has become an essential measure to optimize the health system. The health system has upgraded informatization to a strategic level. All departments earnestly practice and constantly improve. Inspired by informatization, the health system has made considerable progress. The health sector is a part of the medical industry, so the information construction needs to start from scratch. The technical requirements in each field are large, and the business scope of the health system is complex and cannot be fully met, such as medical examination items, drug names, etc. Medical terminology and other major standards and codes are much more complex than other information systems (18). Due to the different stages of health development and the objective conditions of some countries in the region, difficulties in coordinating many health law enforcement are also important factors, which hinder the comprehensive development of medical information, as shown in Figure 1. Health information is limited to the traditional governance mechanism. The original drug and health management model has long been aging and has become a closed vertical governance system. Many departments have poor communication and are relatively independent, and information exchange links are weak (19).

2.3. Problems in community health informatization

Regional health informatization is regarded as the future development direction of the medical industry, which inevitably encounters difficulties. Because the research on health information creation has been carried out in the community, several different roads and models have been established and explored, and some success has been achieved. However, many problems, such as capital, technology, talents, standards, organization and construction mode, operation mode, legislation, are related to the future growth of medical information in this region. The purpose of construction is to focus on a single project. At present, there is less communication between systems, low cooperative mobility, and the software system has not been fully used reasonably. However, each department maintains its inherent management mode. Information and resources are not shared, and many application concepts are not developed or collaborated. At present, the hospital management, routine immunization, maternal and child health care,

emergency command and other information construction methods are independent, not united, and do not understand the purpose of information sharing and information construction. Usually, each department is isolated from the rest of the world. Development needs resources and talents. The growth of medical information involves different disciplines and knowledge, as well as compound knowledge talents in the fields of information and health care.

3. Public health information construction based on the community health archives grass-roots management system

3.1. Building of a health information platform with community residents' health records as the core

The main objectives of the health information platform include: urban and rural residents' information, public health, medical services, medical safety, and drug monitoring. The health information system is established, including important links such as health services. Through the exchange of electronic medical records and electronic medical records, data is exchanged between information systems in different medical and health fields. An identity recognition system with ID card as the main indicator has been established, including the maternal and child health care card, cooperative medical card, medical record information card and other medical and public health related identity recognition means. Community residents are established with health records to provide convenient and high-quality health and medical safety services. On the basis of medical records and medical safety of community residents, a management information system integrating medical service, prevention, health, rehabilitation and education is established. The construction of digital hospitals and digital medical enterprises has been deepened to support hospital management and decision-making, so as to achieve mutual recognition of test results, two-way referral and other medical cooperation (20).

3.2. Elements of health information platform construction based on community health archives

The construction of health information platform aims to collect, integrate, store and disseminate health information to ensure the information sharing of various medical institutions. They carry out business cooperation and exchange information with social security departments civil affairs departments, family planning departments and other departments, which provides data support for the cooperation of various health departments, supervision and management support for medical collaboration, and health information services for residents. The Internet is used to provide community residents with information disclosure, information retrieval, health consultation, health improvement, online registration, appointment, remote consultation and other services. The epidemic prevention plan is subject to self-assessment, health management, etc., including community residents' health card, sharing medical files and cooperation with medical companies. The independent choice of hospitals and doctors is realized to alleviate the

FIGURE 1
Current situation of health informatization construction.
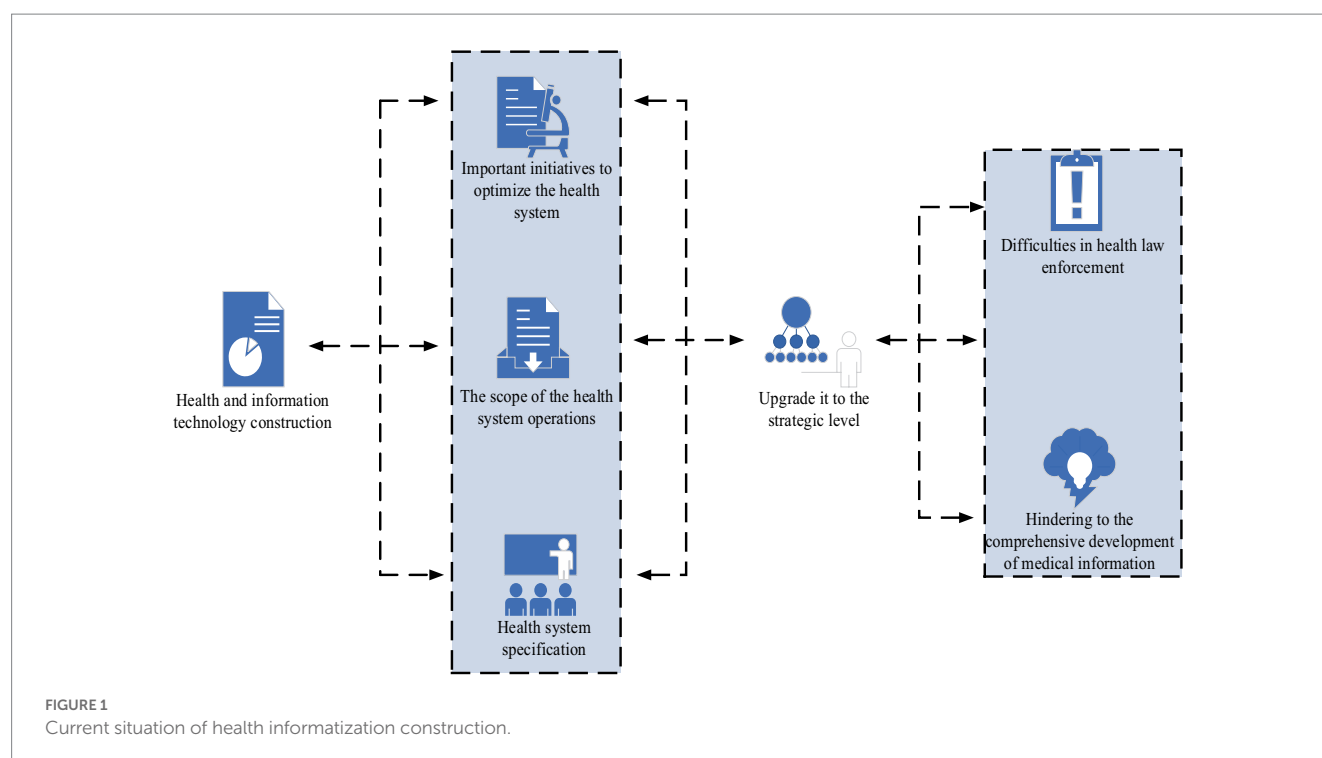
difficulties of expensive treatment, including medical resource management, medical service supervision, public health supervision, basic drug distribution management, financial supervision and medical staff performance evaluation.

3.3. Functional aspects of health information platform based on community health archives

Service capability is improved by standardizing business management. Standardized community health archives are built to create medical information, such as outpatient service, drug management, hospital medical consultation, chronic disease management, etc. The integrity and accuracy of information are ensured to eliminate errors and accidents and ensure medical safety. Outpatient registration requires examination of forms and other written documents. Patients can consult previous medical records to inform doctors of changes and progress of the disease in a timely manner, so as to make accurate diagnosis. The printed prescriptions and various applications from the doctor's office can be paid directly, thus reducing the price. This greatly improves the work efficiency and shortens the waiting time and treatment time of patients, thus saving time. When the health card is used, residents can print the test results themselves to reduce cross infection, thus protecting the privacy of patients and eliminating false positives. Grid address embodies the essence of public health management. The grid address is used to connect personal and family files, and connect to the basic medical public health module, eliminate information islands between different systems, so as to ensure information sharing among residents, and achieve network communication. At the same time, patients can record medical history and track chronic diseases to fully reflect the

characteristics of public health services, and combine prevention with treatment. The health information of residents is dynamically tracked and collected to timely assess their health status. By strengthening medical quality management, the quality of medical service is guaranteed. The information system should conduct a quality assessment every day to check the work quality of all health departments at any time, so as to find and solve problems in a timely manner, which continuously improves the quality of services, controls the growth of expenditure, and reduces the burden on the public. By controlling the number of days, frequency and single dose of medication, as well as monitoring the average cost, the medical expenses of patients can be controlled to reduce the burden of medical care, and reduce medical expenses. Drug supervision should be improved to achieve dynamic tracking, as shown in Figure 2.

4. Functions of community medical information archives management system

4.1. Composition of community medical information archives management system

Computer and network technology allows the electronic storage and processing of archival information generated by various medical activities in the community health service system. Data sharing is achieved through information transmission and exchange between community health service centers and urban health service centers, as well as disease monitoring and cause of death analysis (21). The medical management of public health services is fully computerized. End user access tools are developed to identify, report and connect decision support systems to enhance the management of community health

FIGURE 2
Functions of the health information platform based on community health records.
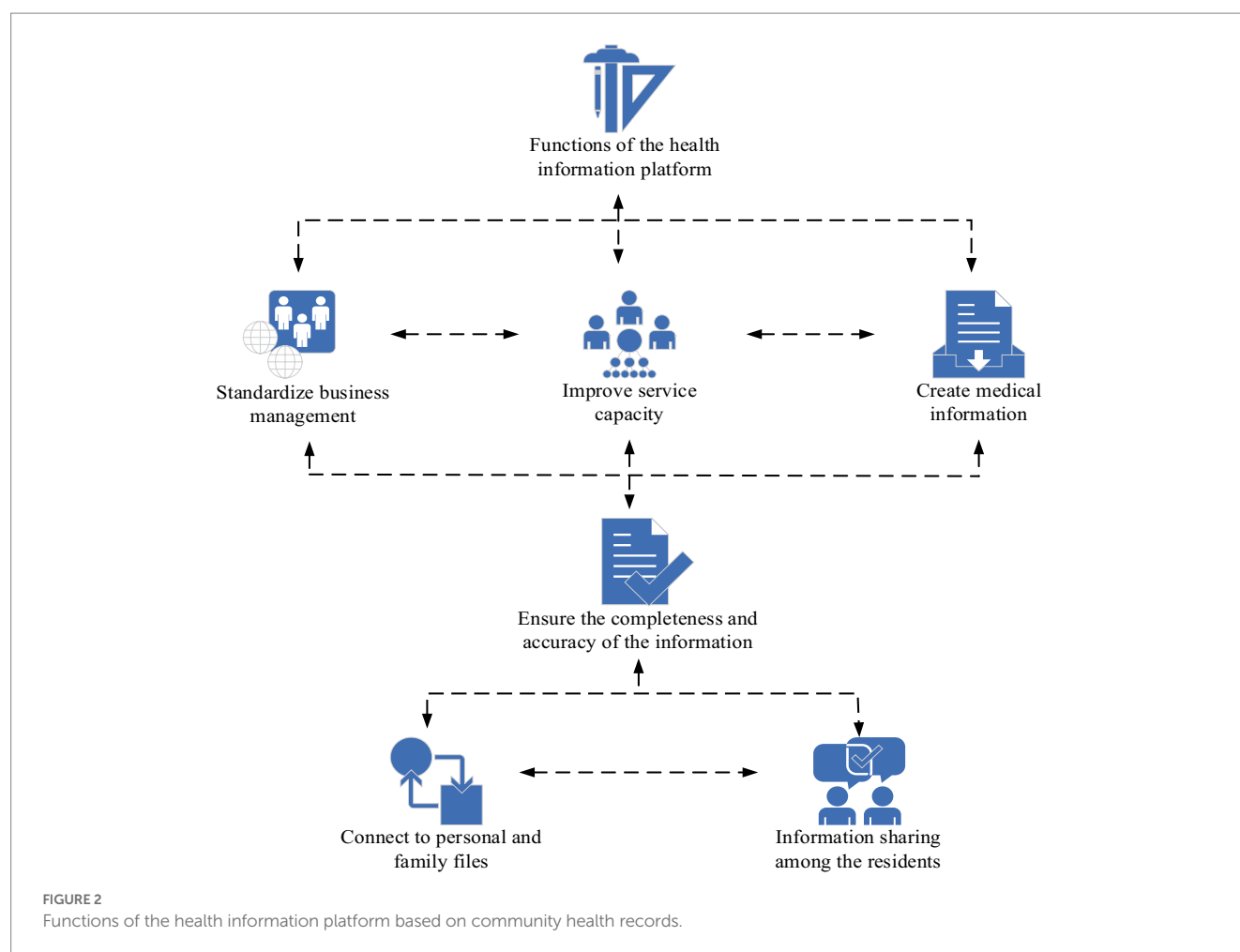
services. The intelligent management system includes personal health records, family health records, physical examination management, child immunization, women's health, children's health, maternal management, infectious disease early warning system, disease management, personal health records and other modules. Drug use, health education, business accounts, etc. can be managed, which is easy to store and retrieve. Data sharing and real-time reporting are required between health service stations and higher level medical institutions. The connection and correlation between good process planning and results evaluation ensure the reliability, accuracy and objectivity of results, and ensure timely service to the common health information sources of the whole society.

4.2. Management and problems of community medical information archives management system

With the rapid growth of medical information technology, community medical information archives management should be at a higher starting point, preferably in the form of administrative management and supervision, as well as the comprehensive standard of information classification, allowing maximum sharing of resources to prevent geographical differences and low compatibility caused by multi-level development. The development of data element standards

and graphic and image transmission standards requires the development of scientific, strict and forward-looking management standards, including organizational management, quality management and technical management. The use of community medical service system resources must comply with the relevant directives and regulations of the Ministry of Health, and ensure the confidentiality of medical records and documents related to the treatment of disabled persons. The system security is strengthened through strict user authority management and password setting to improve modification and other technologies. All regions should be urged to formulate more systematic laws and regulations, regulate the use of relevant information, and take responsibility for illegal use requirements, so that community health information resources can be archived as far as possible to benefit the community, thus ensuring the security of personal privacy and intellectual property rights, as shown in Figure 3.

4.3. Development requirements of community medical information archives management system

The information archives management system in community medical service is a complex multi department, operational and complex engineering system. Its structure and network system consider

the structure and network system of the system from the national or regional perspective. The interface of new methods and new content are maintained to ensure the compatibility and timeliness of the system. The resource sharing between the medical information system and the hospital information management system is improved to meet the needs of reforming and developing the medical service mode through the regional medical information platform. The health data scattered in various institutions is integrated into a logical and complete information base to meet various related management needs. The organic integration of electronic information records, immunization programs, medical information and other professional systems provides comprehensive, sustainable and timely medical service information, as well as data storage and support data markets for management decisions. The health status and risk factors of residents reflected in the community medical service health plan and the health needs analyzed provide a theoretical basis for decision-making and management, and improve the urban health system, thus formulating the community medical service health plan. The online information platform is used to introduce essential drugs, and the detection and use system is established to strengthen drug abuse monitoring. Statistics are compiled to regularly analyse drug abuse in the community. In community institutions, drug abuse is effectively controlled to control the negative trend of drug trafficking. The effectiveness evaluation is integrated to effectively control drug trafficking, so as to establish a reliable efficiency evaluation and distribution mechanism, as shown in Figure 4. The regional health information platform monitors the provision process of public health services, and adjusts the efficiency distribution mechanism according to the total income of community medical service centers and according to the efficiency (22).

5. Strengthening of public health information construction based on decision tree model algorithm

The calculation of expected information for a given sample attribute classification is also called information entropy. Information entropy is a more abstract concept in mathematics, which can be understood as the probability of information occurrence. In general, if a certain information has a higher probability of occurrence, it means that it is more widely spread, and it is usually more widely referenced. It is supposed that x is a sample set of public health informatization, and risk assessment y is a different value. It is assumed that x is that the risk level is the number of samples with different values and a certain risk probability. The expected information required for sample classification is:

$$I\left(x_1, x_2, x_3 \ldots, x_y\right) = \sum_{i=1}^{y} I(x) = \sum_{i=1}^{y} p(i) \log \frac{1}{p(i)} \qquad (1)$$

Among them, pi represents the probability of any risk occurrence probability sample.

The average expected information is the estimated information weight of each direct node branch under specific attribute classification conditions to determine the indicators for monitoring public health informatization. In addition, z has multiple different values. Attribute z can be used to divide the sample x of public health informatization construction into several subsets. The average expected information divided into subsets by z is:
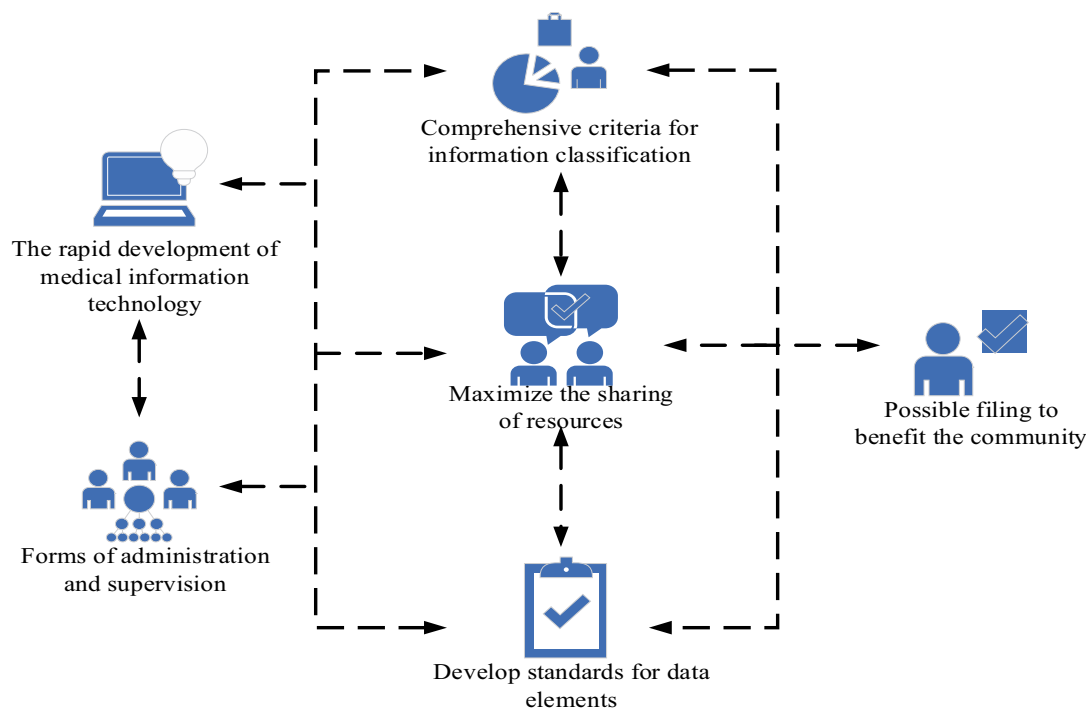

FIGURE 3
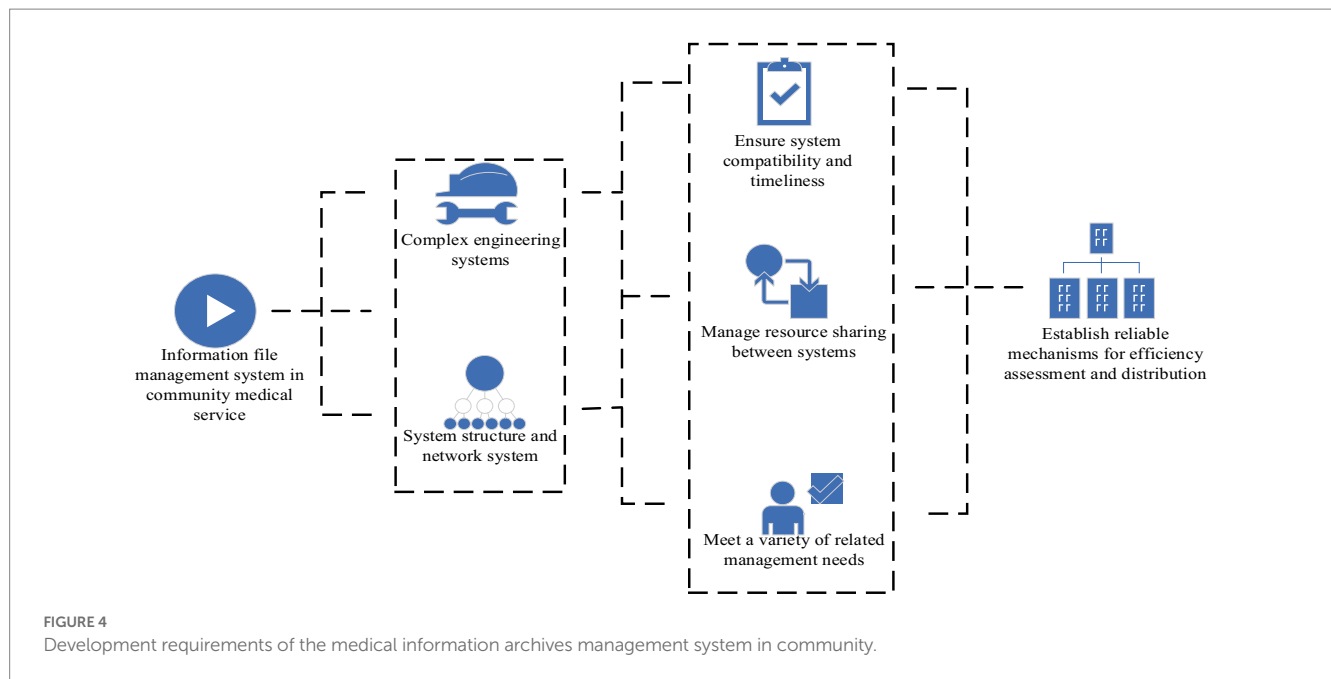Management and problems of community medical information archives management system.

FIGURE 4
Development requirements of the medical information archives management system in community.

TABLE 1 The systematic and use of public health information in health records management.

	Medical service	Drug monitoring	Data contact	Information sharing
A	78%	81%	72%	65%
B	63%	73%	68%	81%
C	82%	76%	71%	75%

$$E(x) = \sum_{j=1}^{y} \frac{z_{j1} + z_{j2} + \ldots + z_{j3}}{z} I\left(z_{j1} + z_{j2} + \ldots + z_{jn}\right) \quad (2)$$

Among them, $\dfrac{z_{j1} + z_{j2} + \ldots + z_{j3}}{z}$ is the number of public hygiene information samples in the subset divided by the total number of public health emergency samples in z, where:

$$I\left(x_{j1}, x_{j2}, x_{j3} \ldots, x_{jy}\right) = \sum_{i=1}^{y} p_{ij} \log\left(p_{ji}\right) \quad (3)$$

z The information gain as a branch of the decision tree model is:

6. Use of decision tree model algorithm and experimental investigation

At present, with the rapid growth of social modernization, people are paying more attention to their own health, and the management of public health archives in the communities where staff work has become increasingly important. To investigate the current situation of systematization and use of public health information in community health records management, this paper investigated different communities in a city. Community workers were investigated on the

current status of public health information systematization and use of health records management. Three communities were selected to conduct a questionnaire survey to investigate the current situation of the use of medical services, drug monitoring, data contact and information sharing in the public health informatization under the management of health records by the staff of these three communities. The three communities surveyed were set as A, B and C, and the number of survey staff was 300. The survey is shown in Table 1.

It can be seen from Table 1 that the current use of public health information systematized medical services managed by health records by community A staff accounted for 78%. The current situation of drug monitoring and use accounted for 81%. The current use of data connection accounted for 72%. Information sharing accounted for 65%. The current use of public health information systematized medical services managed by health records by community B staff accounted for 63%. The current situation of drug monitoring and use accounted for 73%. The current use of data connection accounted for 68%. Information sharing accounted for 81%. The current use of public health information systematized medical services managed by health records by community C staff accounted for 82%. The current use of drug monitoring accounted for 76%. The current use of data connection accounted for 71%. The proportion of information sharing was 75%.

In this paper, the current community health records grass-roots management system of public health information construction status was investigated. The current development status of public health information construction in the grass-roots management system was understood, and residents in three communities were investigated. 150 residents were investigated. In the form of questionnaires, the deficiencies of residents in the current public health information construction of the community health records management system at the grass-roots level were investigated, mainly in the following four aspects: insufficient health monitoring, complex medical information, difficulties in online consultation, and insufficient information resources. The three communities were set as A, B and C respectively, as shown in Figure 5.

Figure 5A shows the proportion of residents in the three communities who have insufficient health monitoring and complex medical information in the current community health records grass-roots management system's public health information construction. Figure 5B shows the proportion of residents in the three communities who have difficulty in online consultation and lack of information resources in the current community health archives grass-roots management system's public health information construction. It can be seen from Figure 5A that the residents of the three communities had different situations regarding the insufficient health monitoring and the complex proportion of medical information in the public health information construction of the current community health records grass-roots management system. Among them, 43% of the residents in community A had insufficient health monitoring on the current community health records grass-roots management system in the construction of public health information, and 36% had complex medical information. The proportion of residents in community B who had insufficient health monitoring in the public health information construction of the current community health records grass-roots management system was 21%, and the proportion of medical information complexity was 33%. The proportion of residents in community C who had insufficient health monitoring in the public health information construction of the current community health records grass-roots management system was 26%, and the proportion of medical information complexity was 16%. It can be seen from Figure 5B that the residents of the three communities had different situations regarding the difficulty of online consultation and the insufficient proportion of information resources in the current community health archives grass-roots management system's public health information construction. Among them, 46% of the residents in community A had difficulties in online consultation on the current community health records grass-roots management system in the establishment of public health information, and 31% had insufficient

information resources. The proportion of residents in community B who had difficulty in online consultation in the public health information construction of the current community health records grass-roots management system was 29%, and the information resources were insufficient was 22%. The proportion of residents in community C who had difficulty in online consultation in the public health information construction of the current community health records grass-roots management system was 41%, and the information resources were insufficient was 19%.

In order to enhance the current development status of public hygiene information in the community health archives grass-roots management system, this paper introduced Internet technology and decision tree model algorithm into the public health information system construction of the community health archives system to build a new public health information system. To understand the effect of the new public health information system, 150 residents in three communities were investigated. The form of questionnaire was adopted to investigate the proportion of residents in the four aspects of insufficient health monitoring, complex medical information, difficulties in online consultation and insufficient information resources in the new public health information system. The three communities were designated as A, B and C. The specific effect is shown in Figure 6.

Figure 6A shows the proportion of residents in the three communities with insufficient health monitoring and complex medical information in the new public health information system (hereinafter referred to as the new system). Figure 6B shows the proportion of residents in the three communities who have difficulty in online consultation and lack of information resources in the new system. It can be seen from Figure 6A that the proportion of residents in community A who were under monitoring health in the new system was 25%, which was 18% lower than the traditional public health information system (hereinafter referred to as the traditional
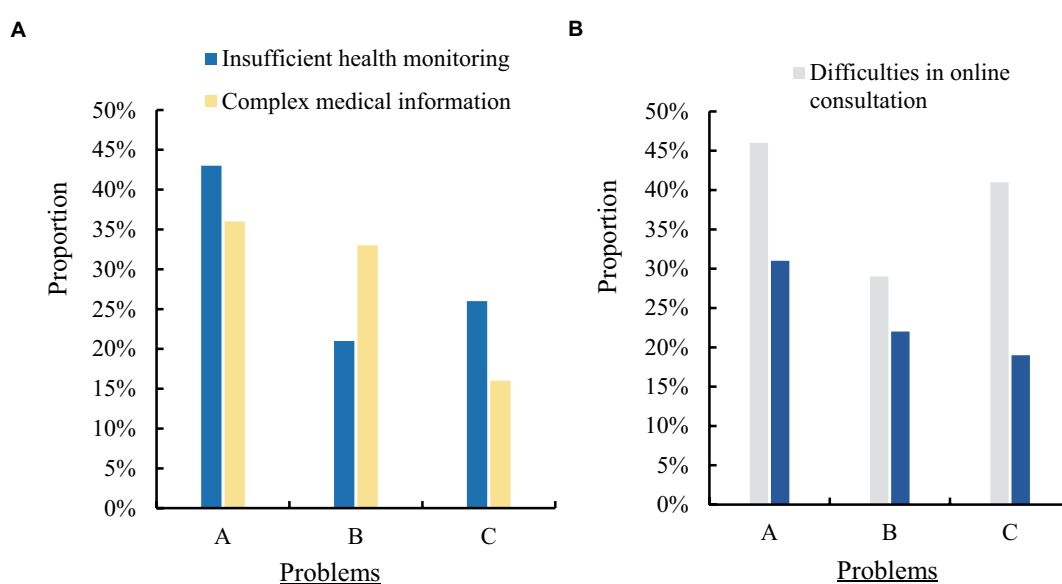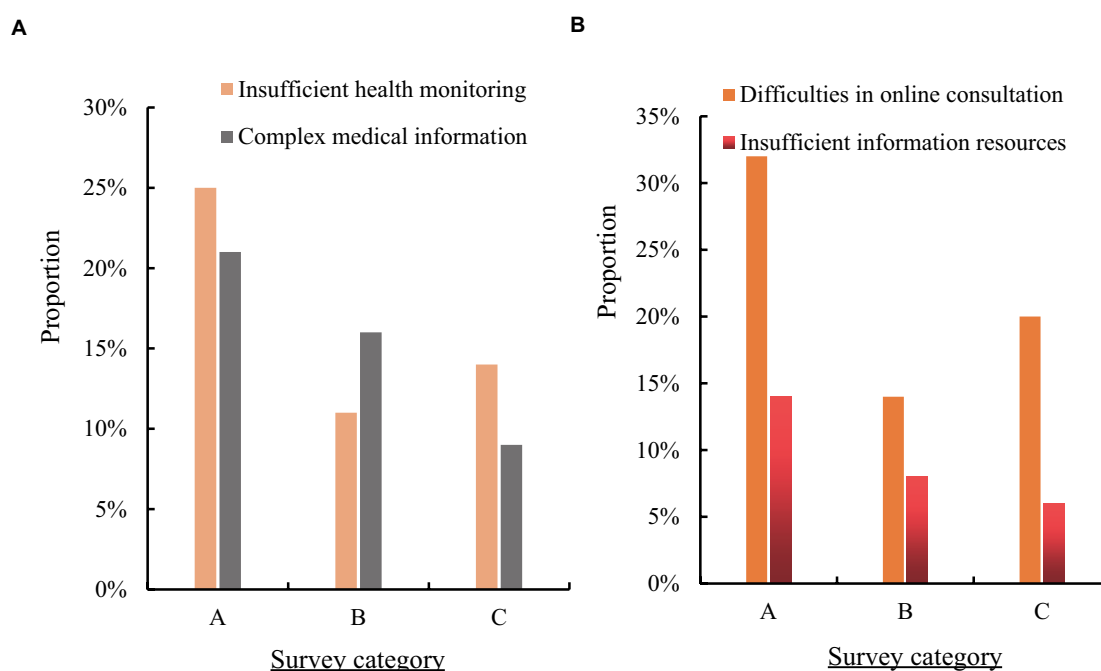

FIGURE 5
Deficiencies of community health archives management system in the current public health information construction. **(A)** Insufficient health monitoring and complex medical information. **(B)** Difficulties in online consultation and insufficient information resources.

FIGURE 6
The effect of the new public health information system. **(A)** Insufficient health monitoring and complex medical information. **(B)** Difficulties in online consultation and insufficient information resources.

system). The complexity of medical information accounted for 21%, a decrease of 15% compared with the traditional system. The proportion of residents in community B who had insufficient health monitoring in the new system was 11%, which was 10% lower than that in the traditional system. The complexity of medical information accounted for 16%, down 17% compared with the traditional system. The proportion of residents in community C who lacked health monitoring in the new system was 14%, which was 12% lower than that in the traditional system. The complexity of medical information accounted for 9%, a decrease of 7% compared with the traditional system. It can be seen from Figure 6B that the proportion of residents in community A who had difficulty in online consultation in the new system was 32%, which was 14% lower than that in the traditional system. The information resources were insufficient for 14%, a decrease of 17% compared with the traditional system. The proportion of residents in community B who had difficulty in online consultation in the new system was 14%, which was 15% lower than that in the traditional system. Information resources were less than 8%, down 14% compared with the traditional system. The proportion of residents in community C who had difficulty in online consultation in the new system was 20%, which was 21% lower than that in the traditional system. Information resources were less than 6%, down 13% compared with the traditional system.

To understand the different effects of the application of the public health information system and the new public health information system in the new community health records grass-roots management system, this paper investigated the satisfaction of residents in a community with the public health information system of the traditional and new community health records grass-roots management system. 100 residents were surveyed, and their satisfaction was satisfactory, average and dissatisfied, respectively. The specific effect is shown in Figure 7.

Figure 7A shows the satisfaction of residents in a community with the public health information system of the new community health records grass-roots management system. Figure 7B shows the satisfaction of residents in a community with the public health information system of the traditional health records grass-roots management system. As shown in Figure 7A, the satisfaction rate of the new public health information system constructed was 84%. The general rate was 11%, and the dissatisfaction rate was 5%. It can be seen from Figure 7B that the residents were 61% satisfied with the public health information system of the traditional health records grass-roots management system, 24% generally, and 15% dissatisfied. According to experiments and surveys, Internet technology and decision tree model algorithm were introduced into the construction of public health information system of community health archives system to build a new public health information system, which could improve 23% satisfaction.

7. Conclusion

In the current social context, information technology has been increasingly applied to the file management, which has become an obvious trend. Community health records are also developing in the direction of information technology. In the current situation, there are still many gaps in the management of community residents' medical records. First, after summarizing the current situation, improvement measures were proposed. A large number of resources have been used to computerize file management, enabling relevant departments to actively cooperate, thus continuously promoting the development of information management, which has laid an effective foundation for prevention and health education to achieve early prevention. The health and changes of residents were directly recorded in the health
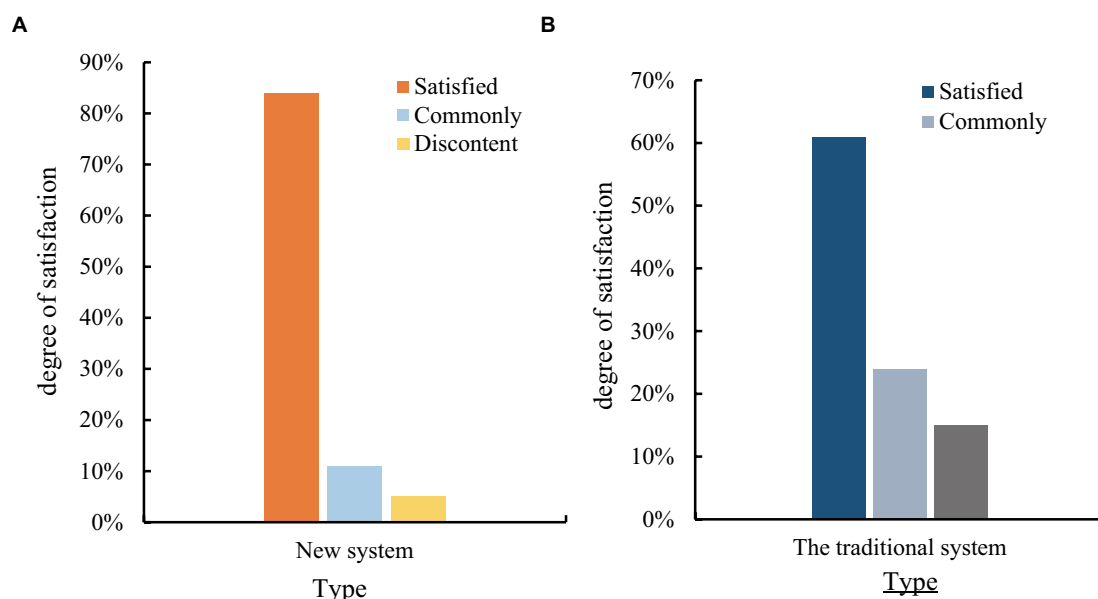
FIGURE 7
Comparison of residents' satisfaction with the public health information system of the traditional and new community health records grassroots management system. **(A)** Satisfaction of the public health information system of the new community health records grassroots management system. **(B)** Satisfaction of the public health information system of the traditional community health records grassroots management system.

records of community residents. The maintenance and use of these records are critical to the health of residents and provide an effective basis for relevant community health work. The reform of the community health system is currently facing serious pressure. The community health record provides an effective framework for work and some effective guidance for people's prevention and health education. Therefore, it is of great practical significance to divide the current community residents' health records according to their arrangement and utilization.

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

YW: conceptualization, methodology, software, data curation, writing. CZ: software, visualization, supervision, writing. 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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Construction of smart older adults care service model driven by primary health care

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In recent years, with the arrival of an overall aging population, how to provide for the elderly has become the focus of government departments and society. The traditional elderly care service model has problems such as backward construction of information platforms, low quality of elderly care services, and "digital divide". For this reason, based on grassroots medical and health care, this paper improves the quality of elderly care services by establishing a smart elderly care service model. Through experiments, it can be found that compared with the traditional elderly care service model, the intelligent elderly care service model has an absolute advantage in the identification of nursing data. The recognition accuracy rate of the smart elderly care service model for all kinds of daily care data is above 94%, while the recognition accuracy rate of the traditional elderly care service model is below 90%. Therefore, it is of great significance to study the smart elderly care service model driven by primary medical care and health.

KEYWORDS

smart senior care service model, traditional older adults care service model, public health, primary medical and health care, pension service quality

1. Introduction

A variety of pension problems arising from the aging process of the population continue to affect China's social and economic progress. As urbanization continues to accelerate, the number of older adult people continues to grow, which has led to an increasing demand for older adults care services. This has added relatively high pressure on government departments and the pressure continues to rise (1). At this stage, practical research on smart senior care service mode has begun in many places. However, from the current actual situation, there are still some problems in the development of the smart senior care model, such as restricted by the structural imbalance of "supply and demand dislocation" of China's older adults care services, the shortage of smart older adults care products and the insufficient supply power of the community smart older adults care products market. This requires improving the level of resource optimization and configuration of the smart senior care service platform to provide professional resources for the smart senior care service model. With the popularity of the concept of a new smart city, information technology and communication technology for public services based on a variety of technologies emerge endlessly, such as public service information technology based on high-speed broadband transmission, Internet of Things, mobile Internet, big data, etc., increasing and expanding the connotation and extension of public services. The "smart senior care" service industry is one of the common industries for the implementation of new smart cities (2, 3).

Smart pension can further reduce the information asymmetry between the supply and demand sides. Various resources of senior care services are integrated to optimize the efficiency of distribution and supply of service resources and provide direction for the growth of senior care services.

With the aggravation of aging, nowadays, people pay more and more attention to senior care services. How to better build a smart older adults care model is a topic that many experts and scholars are studying, and research literature is also emerging in endlessly. Jin Xinyu proposed an organic connection with the three pension modes of institutional older adults care, community older adults care and home-based older adults care by taking diagnosis and treatment of large hospitals as the leading role and using the Internet. He integrated the new technology of artificial intelligence cloud diagnosis, treatment, and rehabilitation of geriatrics to establish the older adults care model of "medical and nursing wisdom linkage" (4). Liu Lijuan used a decision tree classification method to classify retirement data in order to more accurately predict the retirement intentions of older adult people in the community. By comparing the information gain and information gain rate of the sample data features, he determined the feature ranking and built a decision tree model (5). Shi Lifang explored the opportunities for the growth of smart older adults services in both urban and rural areas, breaking the urban–rural dichotomy and encouraging urban and rural areas to enjoy the benefits of reform and development (6). Li Chunsheng suggested an effective multidimensional attentional convolutional neural network model to analyze customer review texts and predict the quality of senior care services (7). There are a variety of research methods used by researchers in smart older adults care services, but little consideration is given to the use of grassroots medical and health drivers to study them.

Some researchers have other views on the research of smart older adults care service model. Wen Zhi proposed a comprehensive hybrid aggregation method with personalized quantifiers to select older adults service providers, where the personalized quantifiers used cubic spline interpolation to determine the location weights of the criteria (8). Sun Weipin believed that a sound social old-age security system could not only meet the needs of the older adults, but also make young people worry free. He provided residents with a higher level of pension insurance by studying the operation effect of the system (9). Jung Soo-Yong took the scientists and technicians of small and medium-sized enterprises who had joined the older adults care service as the research object to investigate the impact on the intention to continue to join the older adults care service. He found the difference between safe and profitable participants in older adults care services. He collected data through questionnaire survey and conducted empirical analysis (10). Wei Yuanting considered non-profit organizations as a potential social capital and an essential force to complement the work of older adults care. He explored the path through social surveys and studied the participation of non-profit organizations in social older adults care services (11). Many scholars have studied the older adults care service. Therefore, this study is meaningful.

How to truly understand the new definition of intelligent older adults care should not only stay on the surface, but also emphasize its artificial intelligence and high-tech services. The wisdom of smart senior care is penetrated into all aspects of personalized older adults care, which requires close integration of smart technology and older adults care services. Primary health care drives are applied to various segments, such as older adults care products, services, management,

operation, and supervision, to enrich the content of older adults services, thus building a synergistic smart older adults service model.

2. Smart older adults care service related theories

2.1. Smart older adults care

Based on the information technology such as Internet technology and wireless sensor network, the smart older adults system can help medical personnel and children to remotely monitor the daily life condition of the older adults and precisely locate their geographical location and the number of various health indicators, which can effectively prevent the occurrence of tragedies (12). The key to smart aging is to link the older adults with home care, nursing and other older adults service practitioners with the help of cutting-edge technology management methods to form a special unity of older adults services and an organic whole that can provide the older adults with interconnected, intelligent, more efficient and convenient older adults care services. It can, in turn, provide professional services for the living condition and recovery of the older adults, so that they can live a peaceful, physically and mentally healthy and happy daily life in their old age (13). It is to utilize a variety of modern information technology means, such as the Internet, the Internet of Things, social networking, big data, cloud computing, wireless sensor network systems, and other modern information technology means, to create an information platform to closely integrate with homes, communities and senior care service institutions. With the requirements of the older adults as the starting point, relevant data are automatically detected, analyzed, forewarned, communicated, responded, accurately positioned, and actively processed in real time to support and meet the needs of the older adults to the greatest extent. The features of the intelligent senior care service platform are shown in Figure 1.

Under the integration and guidance of high-tech information technology, older adults care services have become more and more intelligent, detailed and diversified (14). Nowadays, smart older adults care services focus on many aspects. Under the premise of enhancing the quality of life of the older adults, the accumulated experience and wisdom of the older adults should also be brought into full play, so that the two can be integrated with each other.

Smart senior care service is a service obtained from the transformation of information technology. Its service mode is shown in Figure 2. Various emerging Internet information technologies are used to construct a smart senior care service platform and integrate senior care service resources including regional senior care service management suppliers, designated medical institutions, senior care service providers, and older adults family members. It can quickly respond to the service requirements of the older adults, and complete the rational connection between supply and demand, thus enhancing the service provision capability.

2.2. Smart older adults care service platform model

The concept of "platform" may have different understandings from different perspectives of the subject field. In the field of social economics, the concept of "platform" is defined from the perspective
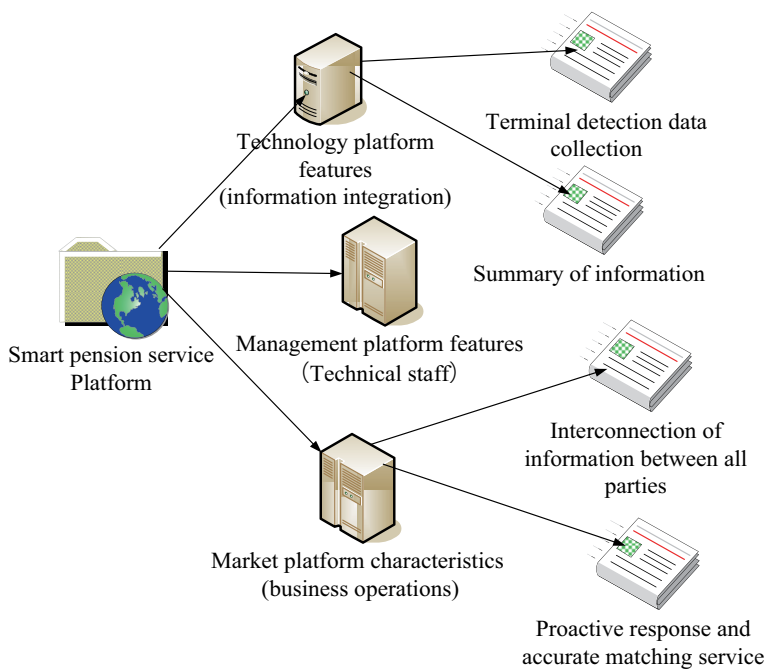
of industry exchange, and it is believed that "platform space" is a space or place to facilitate mutual or multi-faceted transactions, which can exist in the real world, such as large shopping malls. It can also exist in the Internet space, such as e-commerce platforms. The field of enterprise management defines the platform from market competition and enterprise relationship. The essence of the platform is to integrate resources to form a new system to improve its core competitiveness. Science and engineering disciplines emphasize the technical features of the "platform." For example, the basic software platform is defined as an integrated system composed of operating systems, middleware, databases, security products and office suites based on the protocol rules between components.

In terms of smart senior care service model and existing research on smart senior care, the key of smart senior care service model includes two parts. The first is the platform itself, and the second is the smart older adults care service supply mode relying on the platform. As an intermediary between supply and demand, the smart senior service platform realizes its value based on active response and providing intelligent matching services to give reliable business management services. The architecture design of the platform itself reflects the technical characteristics of the platform. Scientific and reasonable system architecture is the material condition to promote the operation of intelligent senior care service platform. The existing scientific research in the field of business operation mode defines the platform business service mode as gathering a number of significantly different but interdependent target customers. The service provision mode of the smart older adults care service platform is in line with the characteristics of the platform's business operation mode to a certain extent. To realize the core concept of the platform, it must be based on information integration and realized by processing a large number of terminal connection management data. The meaning of the smart older adults care service platform includes the business operation mode of the platform, which reflects how the platform creates wealth and gains income, and also includes the corresponding technical architecture. The main content is the overall architecture of the system, the main functional modules to realize the value demands of platform stakeholders, and the key technologies to support the operation of functional modules and realize value creation. The framework of smart older adults care service mode is shown in Figure 3.

The role of smart service platform for home-based older adults care mainly includes three aspects. First, all aspects of data and information collected are integrated and analyzed, and stored in a unified and standardized format for platform developers and customers to share. Second, the ability to purchase senior care services online is provided, enabling the older adults and service providers to complete service connection online. Third, the integration and optimization of older adults care service resources have been realized to assist the government in the management and supervision of the home-based older adults care industry. Therefore, the efficacy of the smart service platform for home-based older adults care mainly includes data information storage services, subsidy evaluation, evaluation and supervision, service personnel training, public welfare resource optimization and allocation management, etc. Details are shown in Figure 4.

Intelligent senior care service platform includes market platform features and technology platform features. The characteristics of the technology platform should be based on information integration, and scientific and reasonable system architecture is the basis for operating

the market platform. The market characteristics of the smart older adults care service platform, as the intermediary between the supply and demand sides, actively respond and accurately match services to provide safe and reliable operation management services, which is the starting point for the smart older adults care service platform to realize its value. The establishment of smart senior care service platform is indispensable to the investment of government departments and social capital. Therefore, its goal in making decisions is to maximize the benefits. When the marginal revenue of the smart senior care service platform is equal to the marginal cost, its own net revenue can reach the maximum. The calculation formulas are:

$$\frac{eW_h}{ex_h} = \frac{b_h \pi}{2\sqrt{\vartheta_h x_0 + x_h}} \tag{1}$$

$$\frac{eW_m}{ex_m} = \frac{(1-\pi)(1-\sigma)b_m}{2\sqrt{\vartheta_m x_0 + x_m}} \tag{2}$$

The marginal cost is $A'_h = e, A'_m = 1 + \vartheta$. Let $\frac{eW_i}{ex_i} = \frac{eA_i}{ex_i}(i = h, m)$, then the calculation formula is:

$$\begin{cases} x_h = \left(\frac{b_h \pi}{2e}\right)^2 - \vartheta_h x_0 \\ x_m = \left(\frac{(1-\pi)(1-\sigma)b_m}{2}\right)^2 - \vartheta_m x_0 \end{cases} \tag{3}$$

Assuming that the cost function is a function of the input level of the participants, the cost of the government and the cost of social capital are:

$$B_h = e(\vartheta_h x_0 + x_h) \tag{4}$$

$$B_m = (1 + \mu)(\vartheta_m x_0 + x_h) \tag{5}$$

2.3. Problems in the smart older adults care service model

2.3.1. Smart older adults care service resources are relatively scattered and service coverage is relatively limited

At this stage, although the smart senior care service is relatively convenient and efficient, the service resources are relatively scattered on the whole. Different types of information service platforms are unrelated to each other. A unified senior care service management system has not been built to integrate various types of senior care service resources to enhance the utilization rate of senior care service resources, thus avoiding the waste of resources (15). At the service provider level, the smart senior care infrastructure is still in the period of pursuing technological progressiveness. Most of the existing smart senior care equipment is built to integrate the development of real
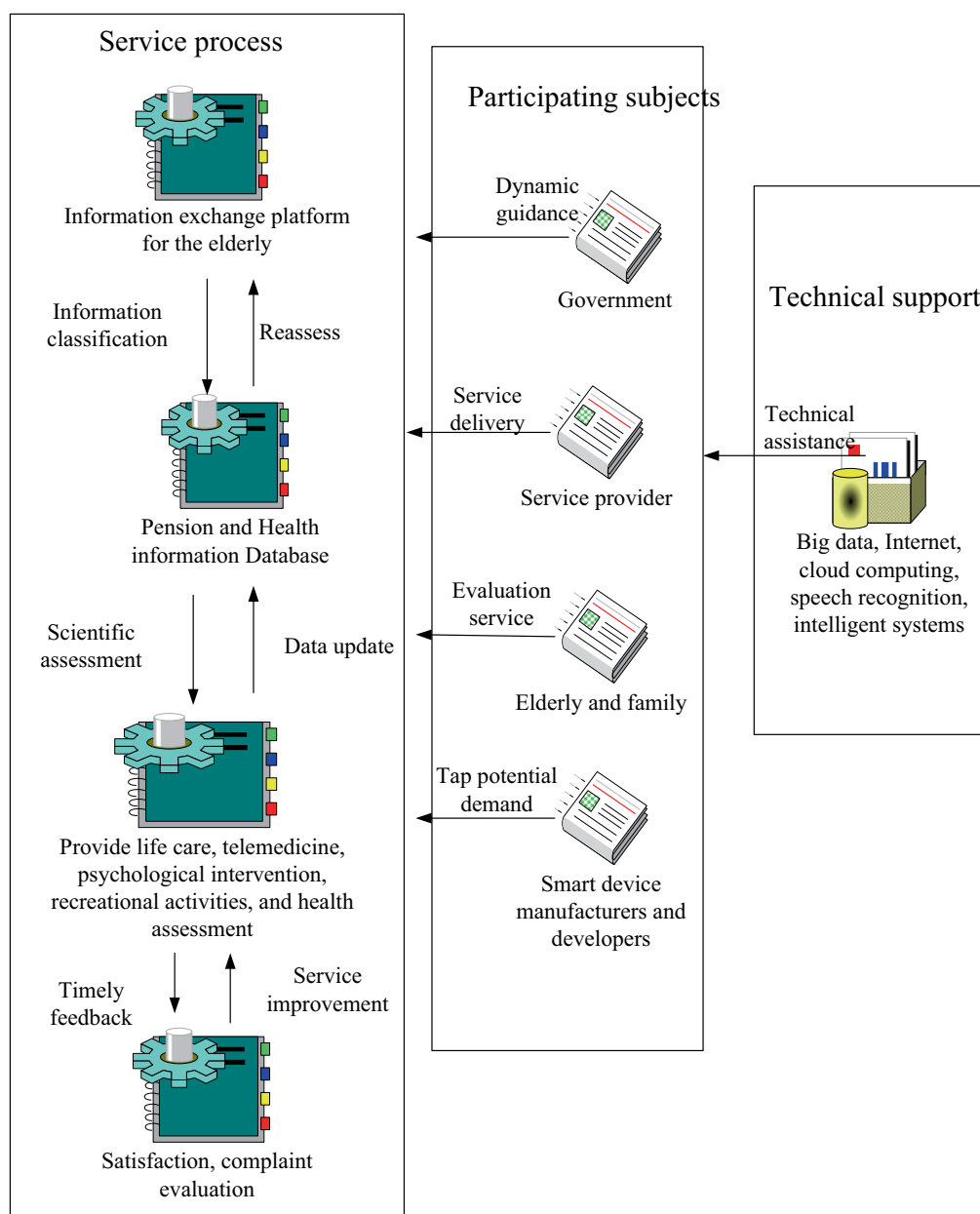
FIGURE 3
Framework of smart older adults care service model.

estate and industrial bases. It is committed to creating high-end luxury equipment or demonstration projects, which has led to some problems. The smart senior care service model driven and guided by grassroots health care has not formed a long-term cooperation mechanism with enterprises and non-profit organizations. The senior care service platform has a series of problems, such as no long-term cooperation mechanism with enterprises and non-profit organizations, limited equipment configuration and technical level, narrow coverage, insufficient promotion, and many other problems. Some high-quality intelligent older adults care equipment, such as intelligent older adults care apartment information system, only cover a part of residential communities and children's welfare homes, and do not expand to a wider range. As a result, smart older adults care service is inconvenient for the older adults to obtain resources due to various factors such as

scattered senior care service resources and limited service coverage, which increases the cost of senior care services.

2.3.2. "Digital divide" impedes the dissemination of smart senior care services

The "digital divide" refers to the difference between the information rich and the information poor (16). Only when the older adults have crossed the "digital divide" can they get smart older adults care services in a real sense. At this stage, government departments have gradually opened various public service information to the public. However, if older persons do not have the ability to obtain such information, they are not able to obtain relevant welfare treatment or services. This is embodied in two aspects. On the one hand, from the viewpoint of the senior, the smart senior care service requirement is

The functions of the wisdom service platform for the older adults.
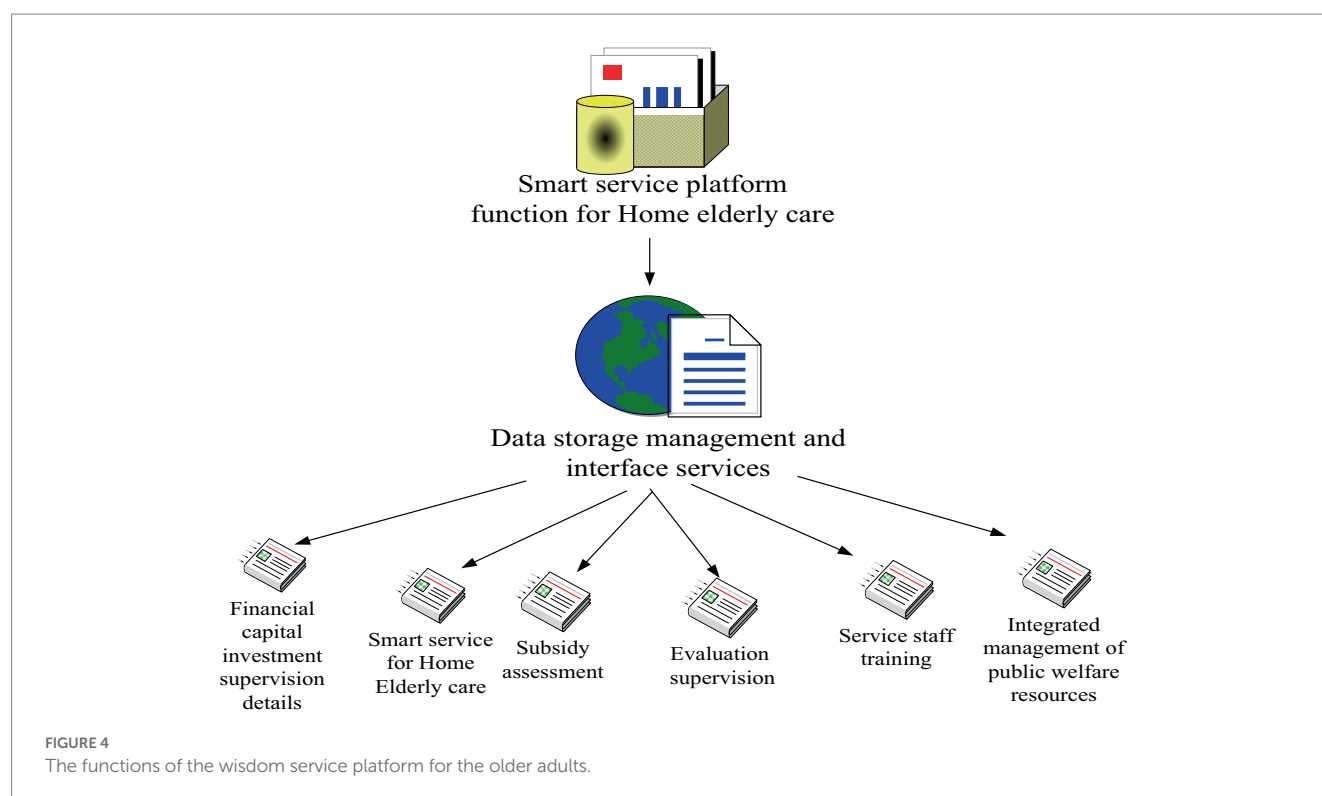
not a valid demand, but only a basic theoretical requirement. On the other hand, the older adult population is unique. For example, due to the values and frugal consumption concepts, as well as the lack of awareness of relevant departments, and the lack of strong publicity and guidance, many older adult people and children have doubts, fears and vague understanding of smart senior care services, which restricts the process of senior people mastering smart new technology products. At the same time, some older adult people are seriously affected by the traditional idea of "inheriting the family" and refuse to accept older adults care services. There are also some older adult people who think it is unhealthy to use high-tech to help themselves live, so they are more resistant to smart older adults care services.

2.4. Overview of the concept of primary health care institutions

Medical and health resources refer to the social resources that people need to apply to carry out medical and health care activities. Broadly speaking, it refers to the general term of various economies of scale consumed or occupied by social development when enjoying medical and health services (17). Medical and health resources can be divided into many kinds. For example, medical and health resources can be divided into human resources (licensed (assistant) doctors, registered nurses, etc.), financial resources (health costs, government subsidies, etc.), and material resources (health institutions, institutional beds, medical equipment, etc.). In addition, it also includes some intangible resources, such as clinical medicine, medical technology, health management, environmental health policies, and regulations. Among them, the primary medical and health resources refer to the primary medical and health organizations, mainly including the medical and health resources possessed by

various clinics. Primary health care organizations are community health centers and service points in large cities. Its primary task is disease prevention and control, health publicity and other public health management, as well as the treatment of some common diseases, which brings convenient and efficient basic medical services to urban residents. It can meet the most basic medical service needs of the masses, and is the core of the new round of medical reform. Primary medical and health organizations are committed to creating a "six in one" service mode and operation mode, that is, taking human health as the center, families as the unit, and streets as the basic scope, which integrates health education, prevention, health care, rehabilitation, family planning, and basic medical care. The schematic diagram of the primary health care delivery system is shown in Figure 5.

Basic medical services provided by primary medical and health institutions mainly include the following three aspects of knowledge. The first is general outpatient and emergency services, mainly including the treatment of common diseases, such as colds or chronic diseases. The second is basic public health management services. The third is proper referral advice, which is mainly for conditions that cannot be treated in primary care. According to the needs of patients, patients are transferred to appropriate designated medical institutions for diagnosis and treatment.

3. Experiment on the construction of intelligent older adults service model

The older adults in City A were investigated, mainly about their basic information and their requirements for smart older adults care services. Five hundred and twelve questionnaires were collected and 500 samples were actually collected. The sampling was mainly based
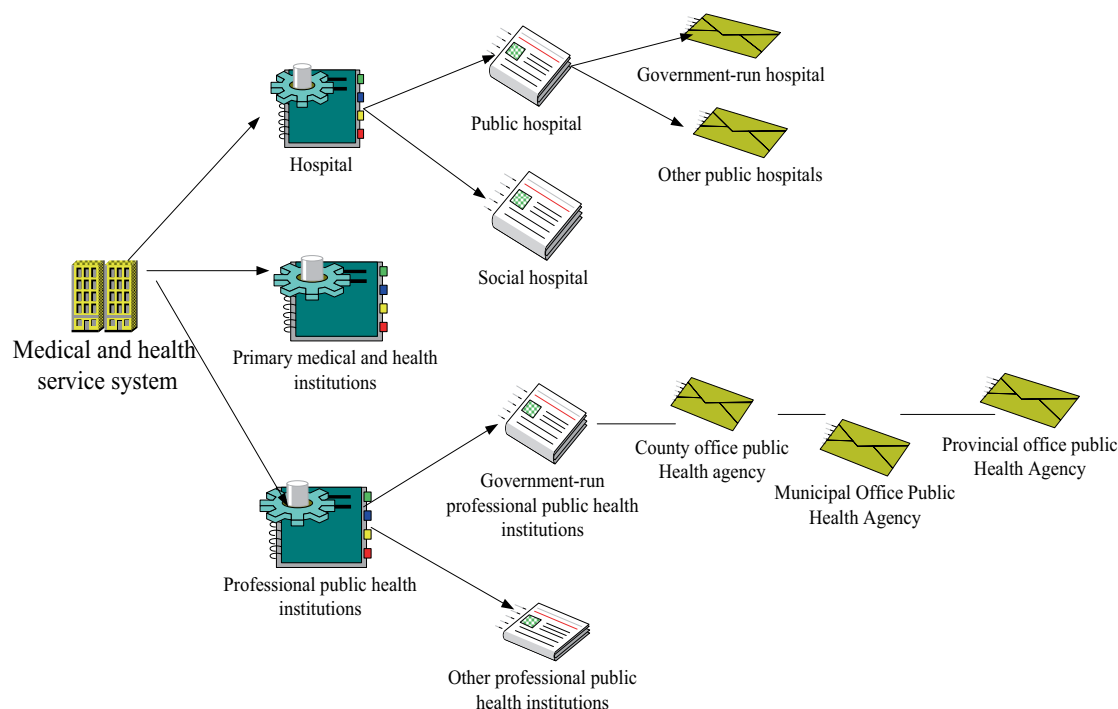
FIGURE 5
Schematic diagram of grassroots medical and health service system.

on the survey of some older adult people in 5 districts of City A, and the survey results are representative. Table 1 shows the basic information of sampling.

As shown in Table 1, the proportion of men and women in the sample is similar, accounting for 48 and 52%, respectively. In terms of age, it is mainly between 65 and 85 years old, accounting for 80%. The older adults aged over 86 accounts for 20%. In terms of monthly income, most of the older adults selected were below 4,500 yuan, accounting for 70%, while those above 5,501 yuan accounted for the least, only 10%. According to the survey on the education level of the selected older adults, the older adults with junior high school education or below accounted for the largest proportion, 48%, while the older adults with bachelor's degree or above accounted for the least, only 2%. Most of the older adults selected lived with their children or partners, accounting for 64%. The older adults living in nursing homes accounted for the least, only 14%. Most of the selected objects still have a certain self-care ability.

For the survey on what demands the extracted seniors have regarding smart senior care services, the specific findings are shown in Figure 6.

As shown in Figure 6, the older adults care service needs of the selected objects were mainly investigated in eight aspects. Among them, medical rehabilitation older adults were highly valued, and the number of people who chose was also the largest, with 130 people choosing, accounting for 26%. The need for cultural entertainment and spiritual solace is also highly valued by the older adults. The number of seniors who chose both was 175, accounting for a high 35%. In addition to the older adults who chose other options, the least number of people chose was cleaning. There were only 35 people chose, accounting for 7%.

At this stage, despite the huge investment in senior care services, the utilization rate of older adults care service resources is not very high. There is even the phenomenon of overcapacity in some places for senior care services, with demand and supply for the senior citizens showing an unstable state. The drive for grassroots health care can integrate the older adults care service resources in various regions, which can help better understand the older adults care service models in various regions. The integration of various resources promotes the development of smart older adults care service model, which plays a role in promoting the growth of smart older adults care service in City A. In this paper, the intelligent older adults care service platform driven by primary health care was used to study the identification accuracy of the basic information of 100 older adult people. These data were tested 20 times. The experimental results were compared with those before the use of grassroots oriented health drive. After using the method studied in this paper for the experiment, the specific findings are presented in Figure 7.

As presented in Figure 7, the smart senior care service platform (that is, after the experiment) driven by grassroots health care was used. The recognition accuracy of the basic information of the selected 100 older adult people was much higher than that of the platform (that is. before the experiment) that was not built based on the grassroots medical and health drive. The accuracy of multiple experiments after the experiment was more stable than that before the experiment, and the fluctuation was controlled at about 1.59%. The fluctuation before the experiment was relatively large, and the fluctuation was controlled at about 7.76%. Among them, the accuracy after the 20 experiments was controlled above 93%, while the accuracy before the experiment was below 88%. Among them, the difference between the basic recognition accuracy of the older adults in the 18th experiment

TABLE 1 Basic information of sampling in City A.

Problem	Option	Number of people	100%
Gender	Male	240	48
	Female	260	52
Age	65–75	200	40
	76–85	200	40
	Over 86 years old	100	20
Monthly income	Below 3,500 yuan	200	40
	3,501–4,500 yuan	150	30
	4,501–5,500 yuan	100	20
	Above 5,501 yuan	50	10
Education level	Illiterate	220	44
	Junior high school education or below	240	48
	College degree or below	30	6
	Bachelor degree or above	10	2
Residence status	Living alone	110	22
	Live with children	100	20
	Live with a partner	220	44
	Nursing home	70	14
Take care of yourself	Cannot take care of yourself at all	80	16
	Can' take care of yourself	300	60
	Can take care of yourself	120	24

before and after the experiment was the largest, which was 14.7% higher than that before the experiment.

The smart senior care service model promoted by primary health care was more intelligent than the traditional senior care service. It can improve personalized senior care services, and also help medical personnel to monitor the physical condition of the older adults in real time according to the intelligent service platform. Based on the smart senior care service model, it can accurately identify the medical advice, medication dosage, nursing records, living habits, and preferences of the older adults. Its recognition accuracy was higher than that of the traditional senior care service model. It can also better verify the medication status of the older adults, so as to reduce medical negligence and safety accidents. The specific comparison findings are illustrated in Figure 8.

As illustrated in Figure 8, the accuracy of intelligent senior care service mode in identifying various daily nursing data of the senior was higher than that of conventional senior care service mode. The identification accuracy of all kinds of daily nursing data of the smart senior care service model was above 94%, while that of the traditional senior care service model was below 90%. The intelligent senior care service model had the highest recognition accuracy in terms of drug dosage, 96.2%, which was 7.5% higher than the traditional senior care service model. The intelligent senior care service model had the lowest accuracy in life habits, only 94.1%, but was still 6.5% higher than the traditional senior care service model. The traditional senior care service model had the highest recognition accuracy in nursing records, 89.1%, but was 5.7% lower
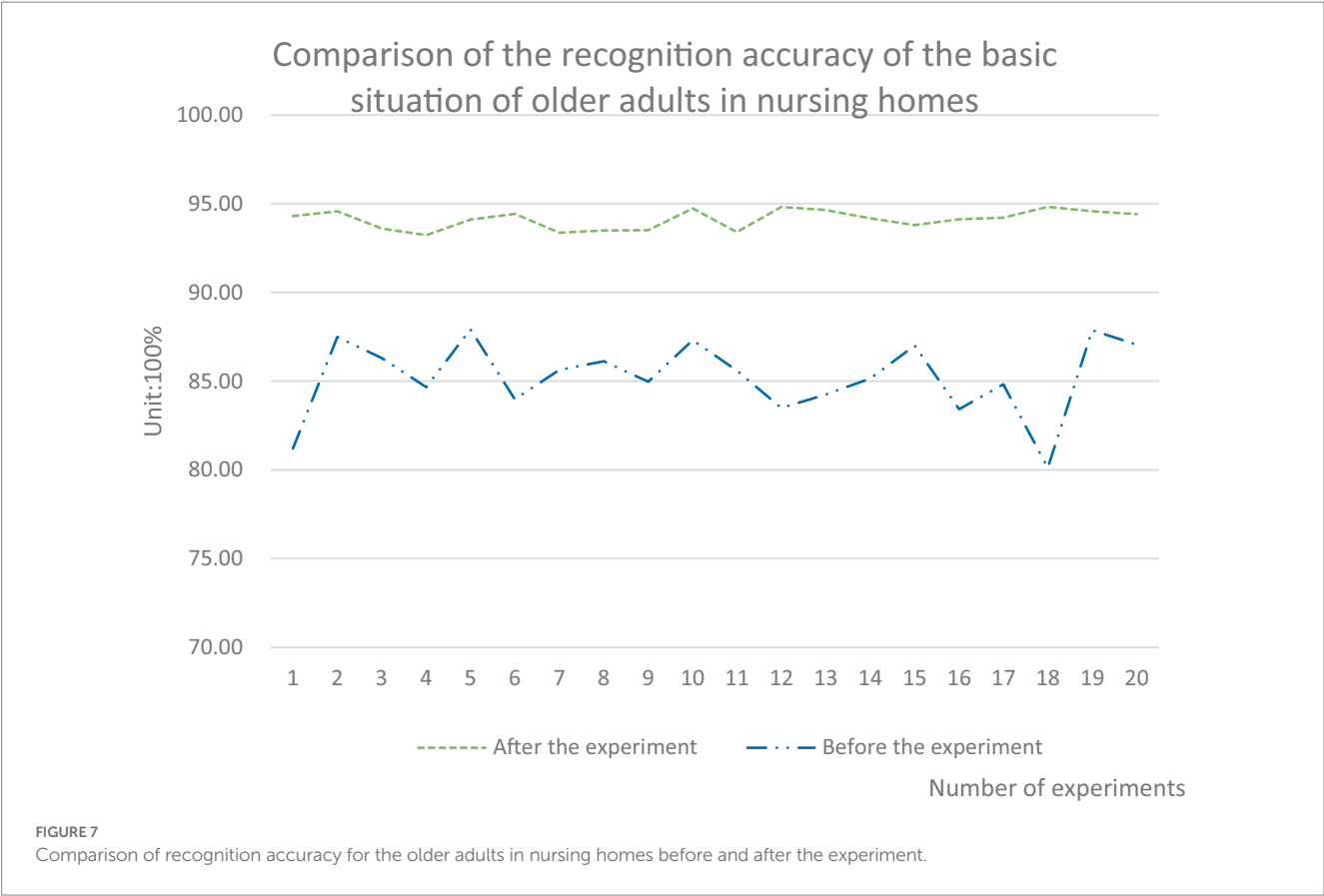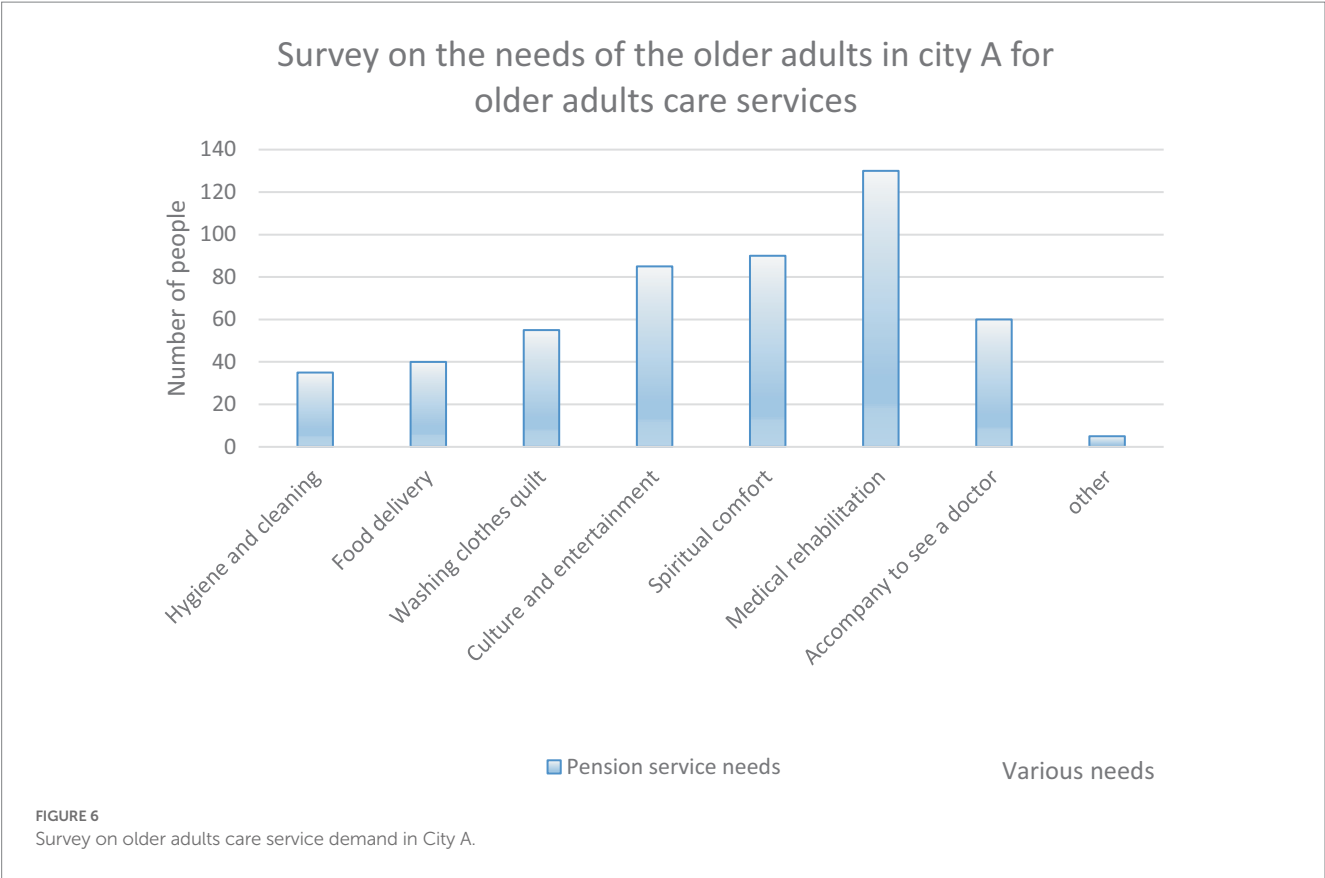
than the service model studied in this paper. The conventional senior care service model has the lowest recognition accuracy in medical advice, only 86.2, 9.3% lower than the service model studied in this paper. The post senior care service model driven by primary health care can record the daily care of the senior into an intelligent system. Doctors can search data at any time, and can further supervise the senior care home services, thus effectively improving the quality of care.
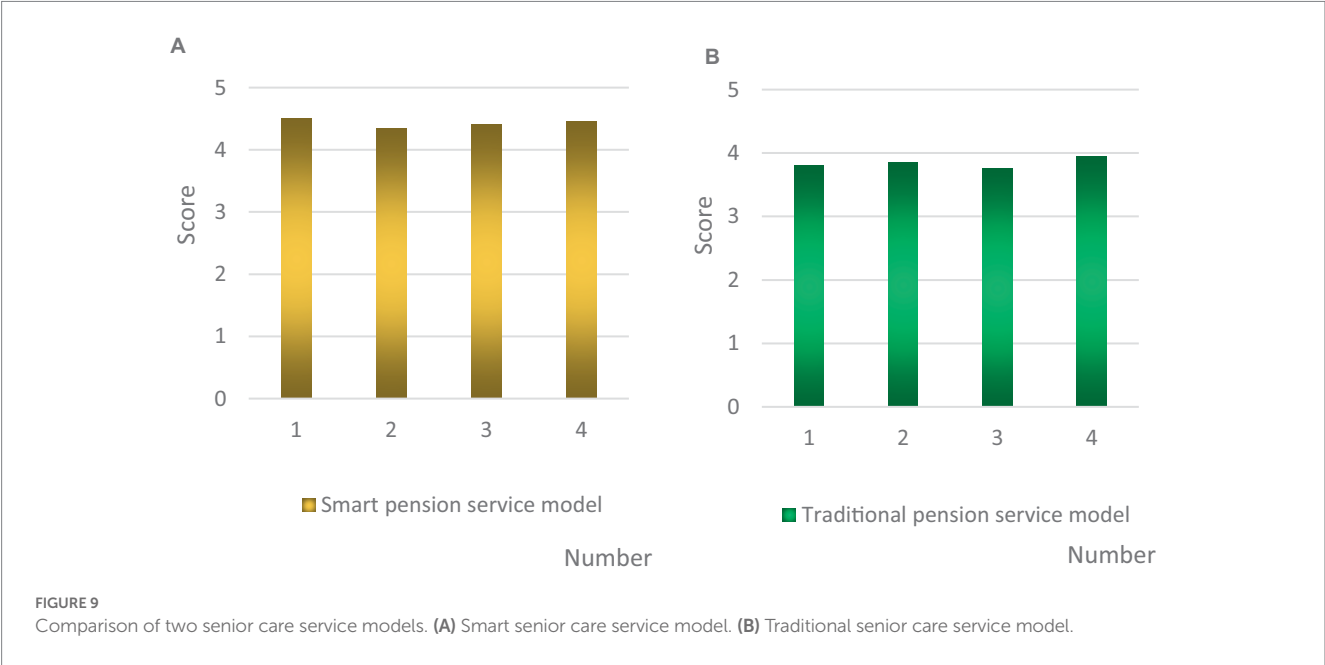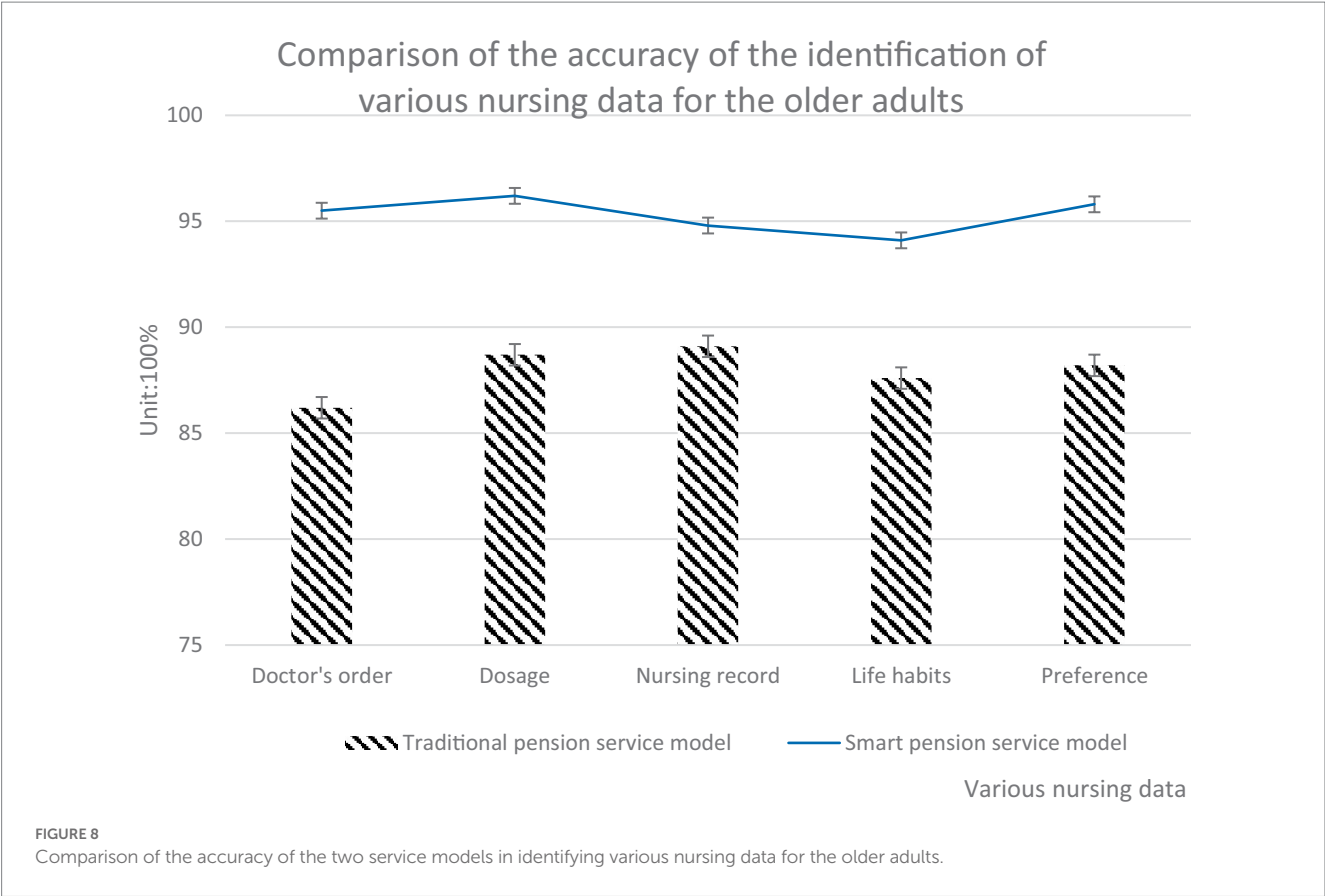
The smart senior care service model driven by primary health care has many advantages compared with the traditional senior care service model. An senior care home that is currently using the smart senior care service model in City A was randomly selected. Twenty staff members were selected from this senior care home to score and evaluate from the four aspects of effective integration of various service resources, realization of the senior multi service mechanism, promotion of the upgrading of senior care service products, and improvement of the construction of senior care professionals. These four aspects were numbered according to 1, 2, 3, and 4. The score was 1–5 points. The higher the score, the better the evaluation. The final result was the average of the scores given by 20 staff members, and the results were compared with the traditional service model. The specific comparison results are shown in Figure 9.

As shown in Figure 9, the staff selected by the smart senior care service model driven by grassroots health care were rated higher than the traditional senior care service model in all aspects. Among them, the score of smart senior care service mode was above 4.3, while that of traditional senior care service mode was below 4. Figures 9A,B were observed. It can be found that the smart senior care service model had the highest score in the number 1 of effective integration of various service resources, 4.5 points, which was 0.7 points higher than the traditional senior care service model. However, the smart senior care service model scored the lowest with respect to the implementation of multi service mechanism for the senior by number 2, only 4.35 points, but still 0.5 points higher than the traditional senior care service model. The traditional senior care service mode scored the highest in the aspect of number 4 to improve the construction of senior care professionals, 3.95 points, but still 0.5 points lower than the service mode studied in this paper. However, the lowest score of the traditional senior care service model was 3.75 points for number 3 to promote the upgrading of senior care service products, which was 0.65 points lower than the service model studied in this paper.

4. Conclusion

As the aging process of the population continues to increase, the needs of the older adults for senior care services are constantly rising. The wisdom older adults service model driven by primary health care is a combination of the state, social development, market, and other multi-participation and multi-faceted cooperation of the senior service system, the core of which is the construction on the wisdom older adults platform. Considering the needs of the older adults, intelligent goods have been developed, which not only need to meet the most basic needs of the older adults, but also pay attention to personalization. The advantages of primary medical care should be fully used to improve the requirements and the quality of senior

FIGURE 6
Survey on older adults care service demand in City A.

FIGURE 7
Comparison of recognition accuracy for the older adults in nursing homes before and after the experiment.

FIGURE 8
Comparison of the accuracy of the two service models in identifying various nursing data for the older adults.

FIGURE 9
Comparison of two senior care service models. **(A)** Smart senior care service model. **(B)** Traditional senior care service model.

care services. The senior care service industry chain has been continuously broadened to promote the healthy development of senior care services with grassroots medical care, and improve the participation and market competitiveness of the senior care market, thus creating a happy and healthy old age for the older adults.

However, the research on smart older adults care services is a relatively cutting-edge topic, and the number of references is limited. In addition, the scientific research ability is not strong, and the research is not sufficient and detailed, so as to strive for further study in the future.

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

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.

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A study on community older people's willingness to use smart home—an extended technology acceptance model with intergenerational relationships

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Introduction: Despite the potential of smart home technology to promote sustainable lifestyles, the adoption rate among older adults remains relatively low. This study aims to investigate the influence of intergenerational relationships on the acceptance of smart home services among seniors.

Methods: A survey was conducted among 298 older adults in China, and data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Ten predictor variables were examined to assess their impact on the willingness to use smart home services.

Results: Intergenerational relationships significantly influenced the utilization of smart home services among older adults. Specifically, intergenerational instrumental support had a direct positive effect on the behavioral intention to use smart homes. Additionally, intergenerational emotional and financial support affected life satisfaction, which subsequently influenced the behavioral intention to use smart homes.

Discussion: The assistance and guidance provided by younger generations play a crucial role in shaping the willingness of older adults to adopt smart home technology. Intergenerational support can contribute positively to enabling aging individuals to age in place through the utilization of technology.

Introduction

In recent years, there has been a significant increase in the older adult population in China (1), which has resulted in new challenges for social retirement. It is essential to note that the majority of seniors desire to live independently for as long as possible to increase their satisfaction and prevent them from incurring costly institutional care. Smart-home services for the older adult focus on providing better aging-in-place services to promote a happier life.

Initially, smart home technologies were developed with a focus on security and energy efficiency (2). As time went by, the range of users gradually expanded to include vulnerable individuals such as the older adult, and people with chronic diseases (3, 4). Smart home services are home automation services based on Internet of Things (IoT) technologies that can be purchased, prefabricated, or installed at home (5). These services include security systems, keyless entry, body detection devices, smart lighting, smart water valves, and more. In the past decade, various smart home services have been utilized to address the unique needs of in-home

aging. Numerous studies have shown that smart home services are beneficial to the well-being of the older adult (6). The benefits of smart home services include independent living, improved healthcare, social involvement, safety, cost reduction, and decision making (7). Therefore, smart home services can help maintain independence and improve the quality of life (8). Scholars have proposed various flexible smart-home service designs to address the specific needs of the older adult (9, 10).

Although technology advancements bring apparent benefits, promoting even the best smart home devices may face potential obstacles such as high expense, technological challenges, safety concerns, burden on others, difficulty in recalling functions, stigmatization, and lack of perceived need (6, 11, 12). Consequently, the older adult do not use them. In China, the adoption rate of smart homes among the older adult remains low (13).

We all know that modern seniors are not entirely resistant to new technologies. They can adopt new technology under the influence of various factors and may even actively try new products. Numerous scholars are investigating the positive attitudes of older adults toward smart-home services and the factors that influence these attitudes. Identifying these positive factors can effectively promote the use of more smart-home services among senior citizens, which can ultimately have a substantial impact on their well-being.

Related works

The Technology Acceptance Model (TAM) is inadequate for assessing the primary factors and barriers to the adoption of smart home services by older adult individuals. To address this issue, Chen and Chan (14) proposed the Senior Technology Acceptance Model (STAM) specifically for the older adult population in Hong Kong, while Pal et al. (15) developed the Older Adult Smart Home Technology Acceptance Model (ESHTAM), a comprehensive model for smart home technology acceptance among older adult individuals. Several studies have examined the factors that influence the acceptance of smart home services by older adults, including personal and environmental perception factors. Personal perception factors comprise perceived ease of use, perceived usefulness, perceived cost (16), facilitating conditions (7), technology anxiety (17), and security and privacy concerns (16–18). Environmental perception factors include social influence (7, 18), subjective norms (15), cultural influence (7), family management policies, and government policies (18).

A literature review conducted by Peek et al. (19) revealed a dearth of valid quantitative studies during the post-implementation phase of technology adoption by older adults. Tsertsidis et al. (20) discovered that the perceptions of older adults regarding technology changed between the pre-implementation and post-implementation stages in their investigation of smart home technology acceptance. They observed that some of the negative concerns expressed during the pre-implementation stage were viewed positively during the post-implementation stage. Similarly, Ghorayeb et al. (11) reported that older adult consumers' approval of smart home monitoring equipment increased with use, in contrast to those who had not utilized monitoring technology. The factors influencing technology adoption also vary across different stages of use in old age. For instance, the longer an older adult individual uses technology, the greater the influence of social factors on their technology adoption behavior (21). Therefore, it is important to focus on changes in the

factors affecting user acceptance attitudes after technology implementation when studying the intention to use smart homes.

Research on technology adoption by the older adult has been criticized for excessively focusing on models such as TAM and UTAUT (Unified Theory of Acceptance and Use of Technology) while ignoring other critical variables. For instance, Chen and Chan's (22) literature review found that despite unique psychosocial factors of the older adult, such factors were often disregarded. Such psychosocial factors may arise from their changing intergenerational relationships.

With the development of technology and the popularization of digitalization, intergenerational interaction and communication have become more widespread and frequent, which also affects intergenerational support (23). Intergenerational support is defined as "the process of economic reciprocity, mutual assistance, and emotional support between generations in a family, as well as the sharing of life experiences and resources" (24). It is a two-way exchange behavior between generations. Studies in developed Western countries have shown that intergenerational support flows from older adults to their offspring. However, research conducted in developing countries indicates that intergenerational support primarily flows from younger to older generations (25, 26). This difference may be due to the fact that in developing countries, older adult care is primarily funded by households rather than the government. Intergenerational support is a broad concept and can be classified into instrumental, financial, and emotional support (27, 28).

Intergenerational support has a significant impact on many aspects of older adults' lives. In general, family support exchange, regardless of the type of support, has a positive effect on the lives of older adults and positively impacts their mental health, self-esteem, and well-being (29–31). Both emotional and financial support enhance physical and mental health (32). There have also been numerous studies on the effect of intergenerational support on technology acceptance among older adults. Seniors who lack daily exposure to new technology are more likely to develop mistrust and negative attitudes towards technological products and ultimately resist adopting new technologies (33). Family structure and communication provide an opportunity to overcome these attitudes barriers. Positive intergenerational interactions can encourage older adults to become interested in ICT (information and communications technology) and start learning about technology, ultimately having a positive external effect on their adoption of new technological items (34, 35). Some studies have shown that the number of minors in the home is positively associated with the willingness of older adults to use Internet technology, although there is no significant effect on the intensity of use (36). However, other studies have found that the presence of children does not clearly explain the adoption of Internet technology by their parents and may be due to the Internet demands associated with having children in the home (37). Further research is needed on the specific effects of intergenerational relationships in families.

Intergenerational support can affect older adults' technology acceptance in several ways. The current focus is on intergenerational technical support provided by children (or grandchildren) to older adults. Grandchildren can encourage grandparents to adopt new technologies by demonstrating and explaining how to use various devices (38). Research has confirmed that the involvement of young "enthusiastic experts" can facilitate intergenerational knowledge transfer and ultimately promote the use of new technologies by older adult users (36, 39). "Enthusiastic experts" provide both intergenerational instrumental and emotional support. He and Huang (40) found that intergenerational technological support has a positive

effect on seniors' attitudes towards smartphone use and their well-being. However, assistance from family members (or intergenerational home care) may act as a substitute for technology, negatively affecting older adults' acceptance of home technology (41, 42), indicating the need for further research. Several studies have examined seniors' adoption of digital feedback (bottom-up technology transfer). Factors that facilitate the acceptance of digital feedback from younger generations by older adult individuals include lower age, higher literacy level, higher economic status, and good family communication practices (43).

Intergenerational support can have both positive and negative effects on older adults' acceptance of smart home services. However, there is a lack of in-depth quantitative studies in this area. The attitudes of older adults towards the use of new technology devices and the type of intergenerational support they receive are unclear, and no research has examined the effect of specific types of intergenerational support on technology acceptance by older adults. There is also a lack of research on the impact of intergenerational financial support. These challenges suggest that intergenerational support should be incorporated into the concept of senior acceptance of smart home services. More quantitative research is needed to determine which factors are most influential. Therefore, this study aims to integrate the TAM model with intergenerational support theory and investigate the influence of three major factors on the willingness of older adults to use smart home services.

Research model and hypothesis

Davis et al. (44) proposed the Technology Acceptance Model (TAM), which has been extensively used as a theoretical model to investigate the intention to use different ICT technologies and intelligent systems. In this study, a TAM-based research model is proposed to investigate the effectiveness of smart home services for older adults.

Perceived usefulness, perceived ease of use, and intention to use

The Technology Acceptance Model (TAM) framework comprises of Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Behavioral Intention (BI). According to TAM, PEOU refers to "the effortlessness experienced by older adults while using smart-home services," whereas PU pertains to "the extent to which older adults believe that smart-home services can enhance their overall quality of life." Previous studies have shown that both PU and PEOU significantly affect the intention of older adults to use smart-home services, either directly or indirectly through attitudes (16, 45).

European and American researchers concur that the effects of PU and PEOU differ significantly between pre- and post-implementation stages (20, 46). Similar conclusions were reached in studies conducted in Asia. For example, when mature Asian users over the age of 40 use the Internet, the impact of usefulness becomes weaker during the initial Internet adoption phase, as compared to the impact of perceived ease of use (47).

The stage of our current study is the initial adoption stage, and therefore, based on the above discussion, we hypothesize:

H1: PEOU has a significant positive effect on the PU of the services.

H2: PU has a positive effect on the BI to use smart-home services.

H3: PEOU has a significant positive effect on the BI to use smart-home services.

Life satisfaction

Life satisfaction is a crucial aspect of well-being, which is a prerequisite for successful aging (48). Previous research has shown that an active lifestyle and participation in social activities can increase the willingness to learn and adopt new technological advancements (49). Moreover, Chen and Chan (14) found that life satisfaction can significantly influence technology use behavior.

H4: Life satisfaction positively influences BI to use smart-home services.

Intergenerational instrumental support

The concept of intergenerational instrumental support is broad and typically includes practical or tangible forms of support, such as household chores and personal care (50). However, in this paper, intergenerational instrumental support is defined in digital technology-related aspects, which are crucial as technology advances and older adults face a "digital divide" due to a lack of digital skills. In response, children and grandchildren in the family may become "passionate experts" who provide digital products to older adults and support them in learning to use various IT products. The intergenerational instrumental support studied in this research includes "children providing intelligent products to older adults along with bottom-up technology transfer" (51). Unlike traditional studies, this work incorporates intergenerational technology support into intergenerational instrumental support, and focuses on the impact of "upward" intergenerational support on BI, whereby older adults are the primary recipients of intergenerational instrumental support rather than providers.

Cao et al.'s (52) study revealed that intergenerational instrumental support not only directly reduces older adult users' resistance behavior towards mHealth application, but also mitigates the impact of negative emotions on resistance behavior. Meanwhile, Eynon and Helsper (39) argued that having children in the household increases the number of Internet accesses for various purposes but does not improve adults' confidence and skills in using the Internet.

Based on the preceding discussion, we hypothesize that the more intergenerational instrumental support older adults receive for information technology, the more likely they are to accept and utilize smart home services. Therefore, we propose that:

H5: Intergenerational instrumental support has a significant positive effect on the PU of the services.

H6: Intergenerational instrumental support has a significant positive effect on the BI to use smart-home services.

Intergenerational emotional support

Intergenerational emotional support is a crucial factor in assessing emotional cohesion between parents and children. Research has shown that older adults who receive emotional support from their children and reciprocate the support are more likely to have higher levels of life satisfaction (53, 54), mental health (55, 56) and well-being (57). For instance, a study by Lai et al. (58) revealed that among older adult Chinese immigrants living in the United States, having closer relationships with grandchildren significantly improved their self-reported quality of life. As quality of life is closely related to life satisfaction (48), this finding highlights the importance of intergenerational emotional support for older adults' well-being.

Moreover, Zhou and Ding (59) found that women who had closer family ties were more likely to receive digital product recommendations and digital technology education from their children. This result is consistent with other studies that have demonstrated how family harmony can enhance digital feedback (60, 61). Thus, it is reasonable to argue that intergenerational emotional support has a positive impact on intergenerational instrumental support.

Chen and Chan (14) investigated the patterns of ICT usage among senior citizens in Hong Kong. They found that older adults who are socially well-connected were more likely to intend to use such technologies, possibly due to receiving more family support. We hypothesize:

H7: Intergenerational emotional support positively affects older adults' life satisfaction.

H8: Intergenerational emotional support positively influences BI to use smart-home services.

H9: Intergenerational emotional support positively influences intergenerational instrumental support.

Intergenerational financial support

Intergenerational financial support includes both downward and upward monetary support. However, studies in China have shown that the older adult are the main recipients of intergenerational financial support, which is the opposite of what is seen in Western countries (25). This difference may be attributed to economic growth and a cultural emphasis on filial piety. Intergenerational financial support has an impact on the psychological well-being of older adults. Numerous studies have shown that higher levels of financial support for older adults are associated with improved psychological well-being and greater life satisfaction (55, 62, 63). Based on these discussions, we hypothesize:

H10: Intergenerational financial support positively affects older adults' life satisfaction.

Demographic data

In the older adult population of Hong Kong, age and gender directly influence the use of geriatric technology (14). In the field of smart homes, Arar et al. (17) reported that age is the most significant determinant of the acceptability of smart home services among the older adult in the UAE. So, the experiment's control variables include age and gender.

Our study aims to investigate the impact of these variables on the acceptance of smart home services among the older adult. Figure 1 displays the specific relationships among the variables based on the research hypotheses mentioned above.

Experimental process

We have developed an online survey tool to measure the perceptions and intergenerational support of the older adult for smart home services. While numerous models of smart home services exist, there is a lack of applicable theoretical frameworks for modeling smart home services for seniors. To address the specific needs of the older adult, we focused on the primary design guidelines found in past literature and extracted a smart home model that is more suitable for their well-being (10, 12, 15). Figure 2 illustrates the model's five dimensions: Environment Monitoring (EM), Health Monitoring (HM), Community Management (CM), Amenity Improvement (AI), and Risk Management (RM). For the sake of user comprehension, the model omits the technical description of information collection and transmission.

Due to the tendency of seniors to rely on heuristics when making decisions (64), additional questions were included in the survey to trigger semantic processing. To facilitate the comprehension and recollection of smart home systems and devices used in their lives, we presented each of the five dimensions of the smart home model in the form of questions and asked respondents to rate the usefulness of five devices using a seven-point Likert scale. Previous studies have demonstrated the effectiveness of similar methods (65, 66). As most of these studies focus on users over the age of 55 (14), we also restricted our study to this age group. Before distributing the questionnaire to the target population, we consulted two independent experts in the field of user experience to check the validity and consistency of the developed questionnaire. We used a convenience sampling method, creating a link to the questionnaire on the website "Wen Juan Xing" and distributing it through several WeChat chat groups. Older Adult people in the groups completed the questionnaire directly, while younger members of the groups sent the link to their senior relatives to complete the survey.

As technological products become more prevalent in homes, an increasing number of senior citizens are adopting smart home technology. However, due to their inexperience with smart home technology, many older adult individuals are not able to fully utilize these systems. Furthermore, the stage of adoption can affect the level of technology acceptance and influencing factors among older adults who use smart home services (20, 47, 67). To ensure the accuracy of the data, we screened senior adults who had used smart home products using a series of questions designed to reduce hypothetical answer bias among participants who had never used a smart home. Specifically, we included a screening question: "Have you ever used
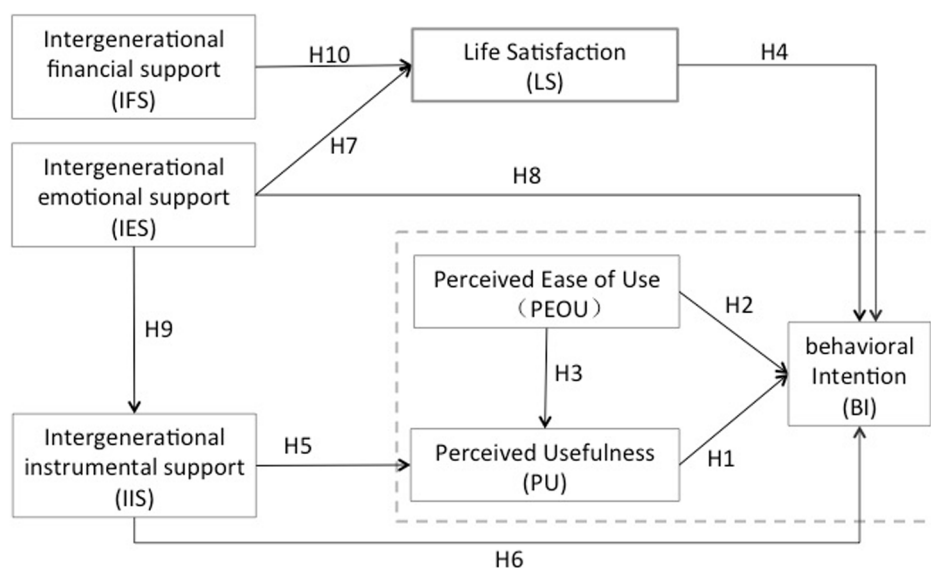
FIGURE 1
Theoretical framework and hypotheses. Control variables: gender, age.
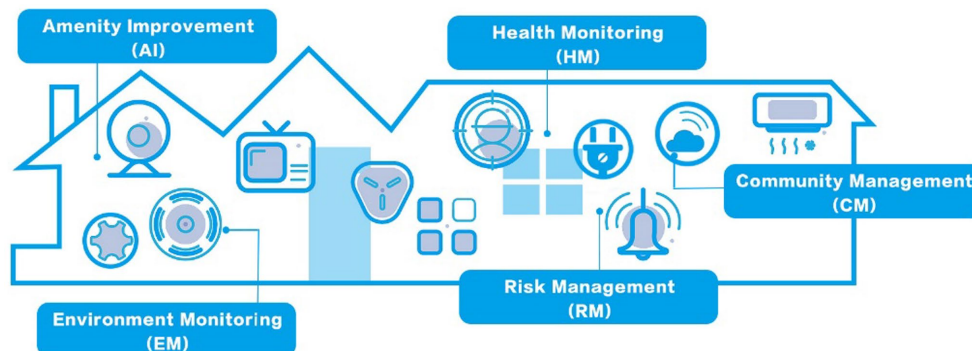

FIGURE 2
A universal model of smart home services that meets the well-being of the older adult.

smart home technology/services?" Response options included "often," "occasionally," "not sure if I have used it," and "have not used." Users who answered "not sure if I have used it" and "have not used" were filtered out and did not continue with the survey.

We measured intergenerational emotional support through three questions, adapted from the Intergenerational Solidarity Survey (68). Since intergenerational financial support includes gift-giving (62), we asked the respondents if they had received any monetary or gift support from their children in the 2 years prior to the survey in order to determine the level of intergenerational financial support. Considering the high cost of smart home technology and its prevalent use in urban areas, this study attempted to distribute questionnaires mainly among the older adult population residing in urban areas, in order to seek a larger pool of respondents who have used smart home technology. Responses to the questionnaire were rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Table 1 presents the final variable definitions and their corresponding sources.

Model analysis and results

A total of 298 valid questionnaires were collected in this study, with 128 (43%) males and 170 (57%) females responding. The respondents' basic demographic information is presented in Table 2. SPSS20 and Smart PLS3.0 were used to analyze and statistically process the data, with the PLS-SEM technique utilized since it is optimal for exploratory investigations.

To examine the impact of controlling variables on the relationship between the independent variable and the dependent variable, we assessed the model both with and without controlling variables. The findings demonstrated that the difference in standardized coefficients of the independent variable between the two models was less than 0.1. As advised by Becker et al. (72), this suggests that the effects of controlling variables are negligible, and therefore, we presented only the results without controlling variables in the subsequent section.

The collected data were analyzed using Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) methods. First, a CFA was performed on eight constructs (dimensions), as shown in Table 3. For all the constructs used, Cronbach's alpha values obtained were more significant than 0.7 and synthetic reliability (CR) greater than 0.6, which indicates a high degree of internal consistency (73). For each construct, the Average Variance Extracted (AVE) is more significant than 0.5, indicating good convergent validity of the measurement model (74). According to Henseler et al. (75), all the values in the HTMT must be less than 0.90. As presented in Table 4. The results indicate that these constructs fulfill the discriminant validity.

To assess the absence of correlation between measurements, divergent validity was examined. Table 5 displays the obtained results. The diagonal element, which represents the square root of AVE, has a higher correlation level between any two specific factors. As a result, the vast majority of constructs in this study exhibit good discriminant validity (76).

Tenenhaus et al. (77) has presented an alternative method for determining the goodness of fit (GoF). The formula for the GoF value is as follows:

$$\text{GoF} = \sqrt{\overline{\text{AVE}} \times \overline{R^2}} = \sqrt{0.783 \times 0.426} = 0.578.$$

We obtain a GoF value of 0.578, which is greater than the suggested GoF value of 0.36 (77), proving the validity of the model.

The hypothesis testing was done in Smart PLS 3.0. We used the bootstrapping method (78). According to the criteria of Henseler et al. (79), SRMR <0.08 is acceptable, we derived an SRMR of 0.061.

The subsamples were randomly selected from the original data set, and this process was repeated multiple times to create a large number of random subsamples. The results indicate that all hypotheses are supported, except for H7. Table 6 presents the significant results of each path coefficient, and the final theoretical framework is illustrated in Figure 3.

Discussion

The findings of this study suggest that many of the explanatory variables are highly significant, and even after using technology, the Technology Acceptance Model (TAM) still has explanatory power regarding older adults' acceptance of smart homes. PEOU has a significant positive effect on both PU and BI. Although PU also profoundly influenced BI, PEOU (standardized path coefficient of 0.260) had a greater effect on BI than PU (standardized path coefficient of 0.198). This supports previous research indicating a strong link between perceived ease of use and technology acceptance among older adults (80). These findings emphasize the importance of making smart home technology simple and easy to use to meet the requirements of senior citizens, especially by designing appropriate voice interface styles, interface navigation, swipe layout, and button size based on the cognitive behavior of older users (81, 82).

However, Pal et al. (15) found the opposite result in their study of smart home use by older adults, concluding that the influence of usefulness on behavioral intentions is more significant. One possible explanation for this discrepancy could be gender differences;

Venkatesh and Morris (83) suggest that the effect of perceived usefulness on intention should be stronger for older adult men than for older adult women. In Pal's study, men comprised 65.7% of the participants, while in this study, men only comprised 42.95%.

Consistent with Peek's earlier findings (19), our study reveals that although older adults are aware of the advantages of smart homes in terms of increased independence and safety, this awareness does not necessarily translate into a willingness to use them. This may be because many older adult people believe that smart home technology is mainly aimed at older adults who are in poorer health conditions, rather than themselves. Additionally, other barriers may significantly hinder the perceived benefits of using smart homes.

Intergenerational support

Our research suggests that intergenerational support plays a critical role in facilitating the use of smart home services by older adults. Specifically, three types of intergenerational support directly or indirectly influence the usage of smart home services by the older adult. Firstly, the provision of home electronics to older adults, along with training them on the use of technology, can directly enhance their perception of the usefulness of smart home services. Prior research supports this positive effect (51). We believe that intergenerational tools used by children can also aid older adults in connecting with smart home technology. Once older adults experience the practical benefits of smart home products, a positive cycle will be generated, ultimately eliminating apprehensions about unfamiliar technology and resulting in the acceptance of additional smart home services.

Numerous studies have indicated the significance of the social relationships of older adults, including support and guidance from family and friends, in the adoption of technology (14, 17, 33). Due to the importance of family bonds in traditional Chinese culture, many citizens prefer the three-in-a-row model where parents and children provide intergenerational upward and downward support. Therefore, it is crucial to concentrate on the relationship between older adults and their children rather than other relationships when studying the use of smart home technology. This study found that both emotional and financial support predict the intention to use smart homes through life satisfaction. In particular, older adults who received more emotional and economic support from their children reported higher life satisfaction and were therefore more inclined to use smart home services.

An active lifestyle can increase users' willingness to learn new technologies (14). As hypothesized, this study demonstrated that life satisfaction is positively correlated with the willingness to use smart homes among older adults. This suggests that positive emotions enable older adults to manage complex technologies better and be more open to new technological challenges. Boosting their confidence in their ability to use technology allows seniors to establish connections to smart home services more quickly. Since the use of smart-home devices is argued to enhance the well-being of older adults (5, 58), the relationship between life satisfaction and the use of smart homes may be interactive. The greater satisfaction with life, the more likely it is that smart home technology will be used, and this, in turn, may enhance the well-being of older adult users. Ren and Klausen (84) contend that society should encourage the older adult to utilize cell

TABLE 1 Construct operationalization along with descriptive statistics.

Measured variables	Measured question	Items	Content source
Perceived usefulness (PU)	PU1	Using smart home will make my life more convenient	Davis et al. (44)
	PU2	Using smart home can make my life more independent and secure	Moore and Benbasat (69)
	PU3	Using smart home, my life will become more enjoyable	
Perceived ease of use (PEOU)	PEOU1	I think the smart home system is easy to use	Davis et al. (44)
	PEOU2	My interaction with the smart home system is simple and clear	
	PEOU3	I can easily learn how to operate the smart home products	
Intergenerational instrumental support (IIS)	IIS1	My children (or grandchildren) have provided me with electronic products	Lang and Schütze (70)
	IIS2	My children (or grandchildren) have encouraged me to use electronics (or helped me set up electronics)	He and Huang (40)
	IIS3	My children (or grandchildren) help me when I have trouble using electronics I get along well with my children	
Intergenerational emotional support (IES)	IES1	I get along well with my children	Mangen et al. (68)
	IES2	My children are willing to listen when I talk about my concerns and problems	Chen and Chan (14)
	IES3	My children and I are close	
Intergenerational financial support (IFS)	IFS1	My children have supported me financially (living expenses, money, etc.) in the past two years	Chang and Huang (55)
	IFS2	My children have given me money, food, or gifts in the past two years, and they are worth a lot of money	Chen and Chan (14)
Behavioral intention (BI)	BI1	If I had a smart home system, I would use it	Davis et al. (44)
	BI2	I have an interest in using a smart home	
	BI3	I predict that I will use more smart homes in the future	
Life satisfaction (LS)	LS1	In most respects, my life is close to ideal	Diener et al. (71)
	LS2	My living conditions are very good	
	LS3	I am very satisfied with my life	

TABLE 2 Demographic of respondents.

Profile	Sample composition	Frequency	Percentage
Gender	Male	128	42.95
	Female	170	57.05
Age	56–60	207	69.46
	61–65	57	19.13
	66–70	19	6.38
	Over 71	15	5.03
Education background	Primary education	39	13.09
	Junior high school or equivalent	65	21.81
	Senior high school or equivalent	107	35.91
	College degree or above	87	29.19
Monthly Income	Less than 4,000	150	50.34
	4,000–7,000	106	35.57
	7,000–10,000	25	8.39
	10,000–15,000	10	3.36
	More than 15,000	7	2.35

TABLE 3 Standardized factor loadings, CRs and AVEs and Cronbach's alphas.

Construct	Item	Factor loading	Cronbach's alpha	rho_A	Composite reliability	AVE
Behavioral intention	BI1	0.913	0.905	0.905	0.941	0.841
	BI2	0.938				
	BI3	0.899				
Intergenerational instrumental support	IIS1	0.849	0.833	0.838	0.900	0.749
	IIS2	0.881				
	IIS3	0.866				
Intergenerational emotional support	IES1	0.910	0.858	0.871	0.914	0.779
	IES2	0.905				
	IES3	0.831				
Perceived ease of use	PEOU1	0.891	0.888	0.890	0.931	0.818
	PEOU2	0.910				
	PEOU3	0.912				
Perceived usefulness	PU1	0.848	0.839	0.841	0.903	0.757
	PU2	0.872				
	PU3	0.890				
Life satisfaction	LS1	0.918	0.859	0.869	0.915	0.782
	LS2	0.819				
	LS3	0.912				
Intergenerational financial support	IFS1	0.793	0.703	0.879	0.861	0.758
	IFS2	0.942				

TABLE 4 Heterotrait-monotrait tatio (HTMT).

	IIS	IES	PEOU	PU	LS	IFS	BI
IIS							
IES	0.801						
PEOU	0.547	0.477					
PU	0.699	0.663	0.77				
LS	0.57	0.588	0.391	0.487			
IFS	0.47	0.424	0.359	0.385	0.524		
BI	0.527	0.432	0.567	0.588	0.436	0.221	

TABLE 5 Correlation matrix among constructs and square root of AVEs.

	BI	IIS	IES	PEOU	PU	LS	IFS
BI	0.917						
IIS	0.458	0.864					
IES	0.383	0.684	0.883				
PEOU	0.509	0.471	0.419	0.904			
PU	0.514	0.583	0.564	0.665	0.870		
LS	0.382	0.482	0.510	0.343	0.414	0.884	
IFS	0.187	0.360	0.322	0.298	0.307	0.440	0.870

phones more frequently to enhance their sense of well-being. The study by Wu and Chiou (85) suggests that social media use among older adults can effectively improve intergenerational relationships and alleviate depressive symptoms. Building on this research, we propose that increased use of smart home services can also enhance the well-being of older adults, in turn, can lead to a more extensive utilization of smart home services and facilitating aging in place.

Consistent with the findings of Silverstein and Bengtson (56), our study found that intergenerational emotional support provides greater life satisfaction to older adult individuals than intergenerational financial support. Notably, when intergenerational instrumental support was used as a mediator, the indirect effect of intergenerational emotional support on behavioral intentions was significant. However, there was no direct effect between the two.
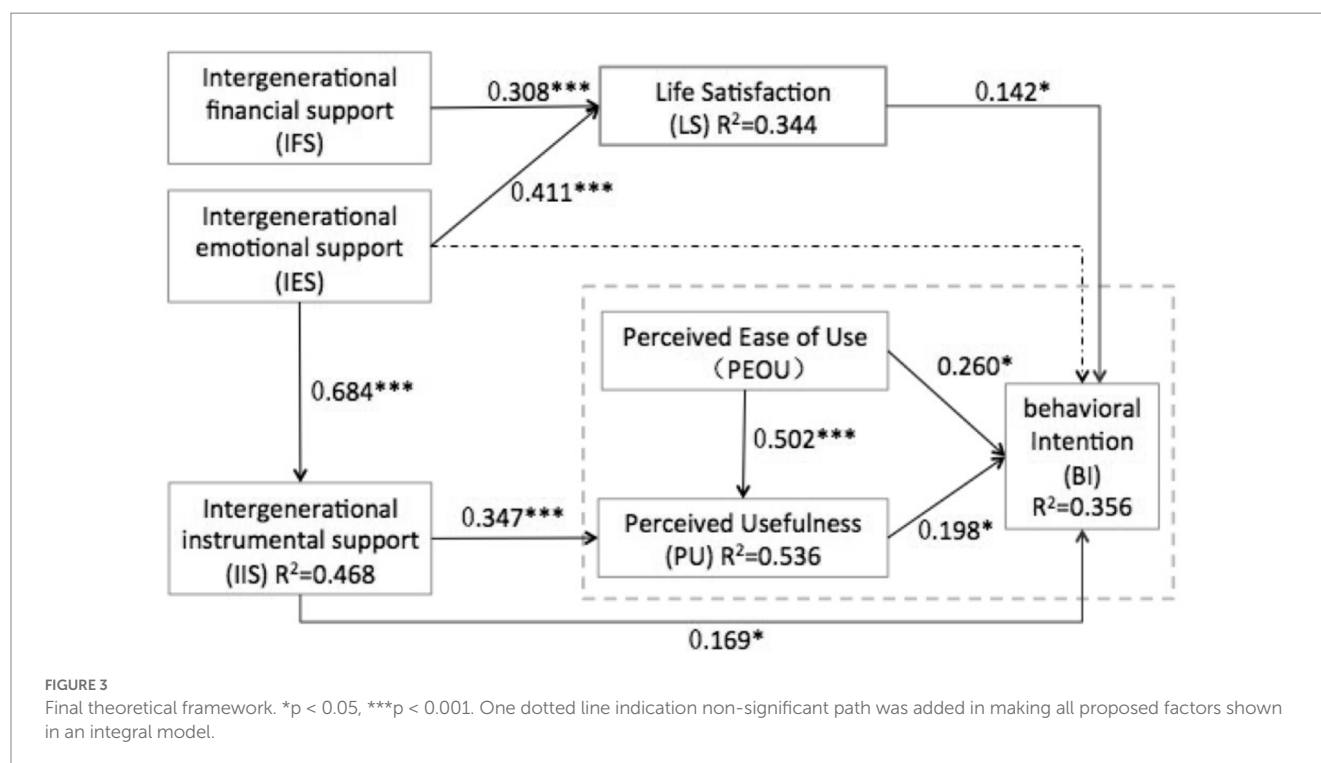
This suggests that emotional support between parents and children is an important factor. Although emotional support cannot directly influence parents' intention to use smart home services, it can facilitate the intergenerational transfer of technological knowledge, ultimately helping to bridge the digital divide among older adult individuals.

Therefore, when promoting smart home products in community homes to enhance the independence of older adults, more emphasis can be placed on the perspective of intergenerational support. For instance, to alleviate negative feelings towards smart homes among older adult individuals, children can present them with necessary products and instructions on how to use them. As mentioned in previous empirical studies, many parents emphasized the importance of their children's concerns when deciding whether they needed a service or technology (86).

TABLE 6 Results of path analysis and hypotheses testing.

Hypothesis	Standardized coefficient (β)	t-Statistics	p-Value	Hypothesis status
PU → BI	0.198	2.326	0.020*	Supported
PEOU → BI	0.260	3.376	0.001*	Supported
PEOU → PU	0.502	9.832	<0.001***	Supported
IIS → PU	0.347	7.226	<0.001***	Supported
IIS → BI	0.169	2.166	0.030*	Supported
IES → LS	0.411	6.808	<0.001***	Supported
IES → BI	−0.025	0.345	0.730	Not supported
IES → IIS	0.684	15.631	<0.001***	Supported
LS → BI	0.142	2.281	0.023*	Supported
IFS → LS	0.308	5.150	<0.001***	Supported

*Significant at $p < 0.05$, ***significant at $p < 0.001$.

FIGURE 3
Final theoretical framework. *p < 0.05, ***p < 0.001. One dotted line indication non-significant path was added in making all proposed factors shown in an integral model.

When using age and gender as control variables, this study found that these variables did not have a significant impact on the model, indicating that older adults' attitudes towards smart homes may be influenced by multiple complex factors. The decline in cognitive ability associated with aging may hinder the acceptance of older adult technology (49), while the decline in health may enhance their acceptance of technology products, as they may view technology as a means of compensating for and facilitating independent living (14). These age-related factors may have either positive or negative effects on the older adult's acceptance of smart homes, contributing to the lack of correlation between age and smart home acceptance. Further research is needed to investigate these factors in greater detail.

Conclusion and limitations

Smart home technology is considered an effective means of supporting in-home aging for seniors, as it can significantly improve their health and independence. However, despite increasing attention, smart homes are not widely adopted among the older adult. Therefore, when developing and delivering smart home technology for older adults, it is important to understand the social supports that influence their use and decision-making, as well as to fully comprehend their needs and provide solutions that are easier to use.

The influence from their family can overcome the fear and rejection of older adults towards smart home technology. This paper

contributes to a better understanding of the factors influencing in the initial acceptance of smart home technology by older adults. When seniors live with their children, they have access to a wide variety of intergenerational support, which can have a positive external effect on them. In Chinese households, which tend to consist of extended families, older adults' acceptance of new technologies may be significantly enhanced. Public policies that incentivize intergenerational interactions can help achieve this goal.

Future research can continue to explore related directions, such as how family relationships affect the number of smart home devices used by the older adult, how to increase their interest in using them, and how to improve their skills. However, the technical maturity of smart home services is currently low and most studies have focused on health monitoring technologies, limiting the possibility of studying the acceptance factors of smart homes after full use.

There are several limitations to this study. First, although the participants were randomly selected, some selection bias may have occurred. For example, many of our questionnaires are delivered to older adult people through their children, so older adult people with high emotional cohesion with their children are more likely to receive this questionnaire that we have sent out. Additionally, the age range of the participants was relatively young, which may not fully represent the intergenerational support and acceptance of smart home services among the older adult population. Hence, the results need to be interpreted with caution. Second, this study provides a general understanding of smart home acceptance. However, there are various categories of smart homes with different levels of usability, ease of use, and purpose, which may influence older adults' attitudes towards them. Therefore, future research should segment the study based on different types of smart homes. Third, the study does not consider the impact of brand influence on older adults' attitudes towards smart homes, as different brands of smart home products have different interfaces and designs. Therefore, future research should take brand influence into account. In conclusion, more research is needed to capture the complexity of the acceptance process of different types of smart home services by older adults in the community to better leverage technology for their aging-in-place.

Data availability statement

Author contributions

WW proposed the idea of this research, wrote the paper, and acquired the funding. XG wrote a part of the paper. KT, JL, and KX collected the data and revised the paper. 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

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Factors affecting access to healthcare for young people in the informal sector in developing countries: a systematic review

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Background: Young people are increasingly seeking employment in the informal sector due to increasing global unemployment. However, the precarious nature of work in the informal sectors, coupled with the high risk of occupational hazards, calls for a greater need for effective healthcare for informal sector workers, particularly young people. In addressing the health vulnerabilities of informal workers, systematic data on the determinants of health is a persistent challenge. Therefore, the objective of this systematic review was to identify and summarise the existing factors that affect access to healthcare among young people from the informal sector.

Methods: We searched six data databases (PubMed, Web of Science, Scopus, ProQuest, Crossref, and Google Scholar), which was followed by hand searching. Then we screened the identified literature using review-specific inclusion/exclusion criteria, extracted data from the included studies and assessed study quality. Then we presented the results in narrative form, though meta-analysis was not possible due to heterogeneity in the study design.

Results: After the screening, we retrieved 14 studies. The majority were cross-sectional surveys and were conducted in Asia ($n=9$); four were conducted in Africa, and one in South America. Samples ranged in size from 120 to 2,726. The synthesised results demonstrate that problems of affordability, availability, accessibility, and acceptability of healthcare were barriers to young informal workers seeking healthcare. We found social networks and health insurance as facilitators of access for this group of people.

Conclusion: To date, this is the most comprehensive review of the evidence on access to healthcare for young people in the informal sector. Our study finding highlights the key gaps in knowledge where future research could further illuminate the mechanisms through which social networks and the determinants of access to healthcare could influence the health and well-being of young people and thus inform policy development.

KEYWORDS

access to healthcare, young people, informal sector, health, informal workers, developing countries

Introduction

Globally, the informal sectors constitute over 60% of the workforce (1). While most developed countries have less proportion of informal workers, 93% of the global informal employment is in low- and middle-income countries, particularly in Asia and Africa (1). It is difficult to identify accurate representation of each nation on a country-to-country basis due to the flawed recording system in many developing countries. The apparent lack of records of their employment and, most often, lack of contract make it very difficult to reach them. However, on a demographic basis, young people account for one of the largest population groups in the informal sector (2). The International Labour Organization (ILO) describes the informal sector as a group of unincorporated production units owned by households, typically small and unregistered enterprises (3).

In fact, there is no universal definition of young people as it varies from context to context (4); however, the United Nations defines young people as people aged 15 to 24, and the African Union defines them as being between 15 and 35 years old (5). Approximately 77% of young workers are employed in the informal sector due to the rapidly changing dynamics of the labour market, such as increased unemployment (6). However, the jobs held by young people in the informal sector typically have low wages, long working hours, and no legal or social protections (6). These challenges, coupled with the daily occupational hazards, contribute greater need for healthcare among young people in the informal sector (7). As of yet, a limited amount of literature has investigated the factors that affect young informal workers' access to healthcare, most of which has been conducted in Asia (7–10) and Africa (11–14). However, these studies focused on diverse groups of informal workers from different geographical contexts.

Access to healthcare has a profound effect on every aspect of an individual's health, yet many young informal workers find it challenging to gain access, putting them at risk of poor health outcomes. Young people's health challenges have demanded increasing attention on the global stage, as reflected in the Sustainable Development Goals (SDGs). One of the 17 sustainable goals is to "ensure healthy lives and promote well-being for all at all ages" (SDG 3) (15). To ensure this goal's achievement (SDG 3), further progress needs to be made towards the achievement of universal healthcare (UHC). Achieving UHC requires the provision of healthcare to everyone, including those employed in the formal and informal sector. Unfortunately, people in the informal sector are mostly excluded from different forms of social protection including health insurance, as a result of their informality (7, 16).

Therefore, addressing this setback requires their access to healthcare. A recent study by Lee and Ruggiero (17) synthesised existing knowledge on the health and health equity implications of informal employment. However, a clear understanding of the factors that either positively or negatively affect their access to healthcare is needed for the health promotion of young informal workers to be achieved. In the light of the limited review-level evidence, our

current systematic review aims to identify, analyse, and synthesise primary evidence on the factors affecting access to healthcare for informal workers, with the focus on young people. To the best of our knowledge, no study has systematically reviewed, analysed, and synthesised this evidence to point out gaps for future direction in the access to healthcare literature and policy implication.

Methods

This systematic review explored the factors affecting access to healthcare and the health and well-being outcomes of young informal workers. In the larger review, health outcomes were grouped in a way that would offer great conceptual and practical value, for example, physical health, mental health, and health behaviours. However, this paper focuses only on the factors that affect access to healthcare for young informal workers.

Given that the purpose of this study was to synthesise existing empirical research to provide a consolidated overview of the evidence in this field and to put out gaps for future research, rather than the generation of a new theory, we adopted an integrative approach which enables the collation of different types of evidence (i.e., quantitative, qualitative, and mixed-methods) (18). The results from all the methods relevant to the identification and synthesis of data on the factors affecting access to healthcare (including factors hindering and facilitating access to healthcare).

Criteria for inclusion

Types of studies

Guided by the integrative approach, we sought to include empirical quantitative, qualitative, and mixed methods studies that were peer reviewed and published in the English language between the years 2000 and 2022. All articles dealing with either empirical or theoretical aspects of access to healthcare are included. After combining the results from the databases, duplicate articles were excluded. Publications without full texts, reports, working paper, magazines, letters to editors, correspondence, conference papers, and books were further excluded from the search results. Figure 1 summarises the search and selection process of the 14 articles in this review.

Types of participants

Studies were included if they focused on young people in the informal sector. The definition of young people in the literature varied in the way's authors defined them. Therefore, we adopted a pragmatic approach, guided by the African Unions definition of young people, as people between the ages of 15 to 35 (5). This definition helped to collate large evidence from the different groups of people classified as young people in the literature. Studies where most of the participants were between 15 to 35 years were also included.

Dimension of access to healthcare

The study of access to healthcare for informal sector workers has been complicated by a lack of conceptual clarity around the term 'access', resulting in different access definitions (20). To ensure that all aspects of access to healthcare are included in this study this study
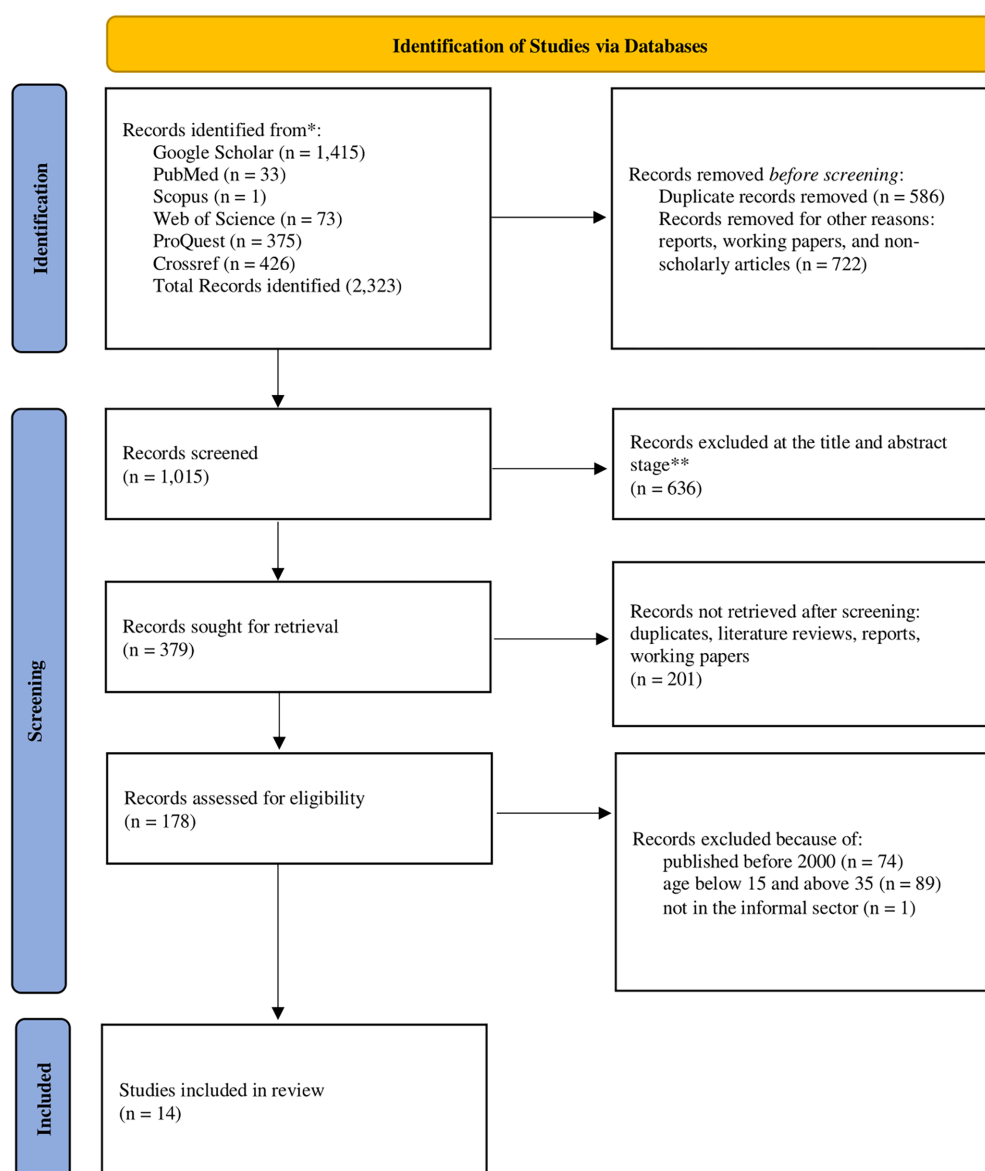
FIGURE 1
Search results and selection of papers (19).

adopted Peters et al.'s (21) access to healthcare approach to frame the discussion. They conceptualise access to healthcare services by using four dimensions—availability of service, affordability, geographical accessibility, and acceptability. This framework would help to capture the various factors affecting access to healthcare identified by the studies under this review.

Databases and search strategy

Data sources

In this systematic review, six bibliographic databases were searched in September 2020 and updated in April 2022, including PubMed, Web of Science, Scopus, ProQuest, Crossref, and Google Scholar. We also hand-searched the reference list of retrieved articles and websites of organisations conducting research on the health and well-being of young people and informal workers. The websites included: The International Labour Organisation (ILO), the Rockefeller Foundation, and Women in Informal Employment: Globalizing and Organizing (WIEGO). Finally, hand searching was also conducted using Connected papers – an online software used to identify related and relevant literature—to ensure that all relevant papers were captured in the review.

Search terms and delimiters

As indicated earlier, the keywords included were broader than just access to healthcare. The keywords included: "young people," "access to healthcare," "access to health services," "access to healthcare," "artisans," "informal workers," "informal sector," and "health," in the title and abstract. We limited the searches to studies published within the year 2000 and 2022 and only studies published in the English language. Retrieved articles were stored in Mendeley. A study protocol

was created, consisting of the study's aim, key concepts, inclusion and exclusion criteria, and database search strategy. The review stages included retrieving search results from the approved databases, extracting duplicates, screening irrelevant data, assessing the retrieved studies, synthesising the data, and creating a report using a flowchart.

Data collection and analysis

Selection of studies

The first step to selecting the studies included in this review was identifying and removing duplicates. All the articles identified from the search were first recorded in Microsoft Excel and tabulated under different headers such as author, title, year of publication, abstract, and cites. The results were initially stratified into six sheets based on the databases they were retrieved from. Each sheet contained the following contents: the article publication date, author(s), title, objective, methods, key findings, population, study site, strength, limitation, and conclusion. These contents helped simplify the data synthesis and cleaning. All the identified abstracts were subject to a two-stage screening process. The authors screened the title and abstracts independently, causing a long screening time, and articles that did not fit the inclusion criteria were automatically excluded. Where no abstract was available, the article was retained to the next stage, which involved screening the full-text subject to the inclusion and exclusion criteria. The entire screening process was double-checked by the two individuals who worked independently of each other.

Data extraction

A review-specific data extraction tool was designed to enable the extraction of data from all studies with different designs. The key elements of the data extraction included the context of the study, such as the geographical location and year of the study, the aims and objectives of the studies, the study design, the participants—the age and the type of informal work—the main findings, and the strengths and limitations. This was also conducted with a review by two individuals.

Quality appraisal of selected publications

The quality appraisal was conducted at the same time as the data extraction. The articles selected for this review were qualitatively evaluated and further reviewed by the first author's two supervisors, who served as external reviewers to ensure that both the selection process and the articles selected were of premium quality. The quality of the articles was assessed before the final selection for review. The assessment was done based on the five-criteria framework designed by Dixon-Woods et al. (18). The five criteria include: were the aims and objectives clearly stated in the article; was the design specified, and was it suited for the research goal; was the research process clearly explained; was there sufficient data to support the interpretation and conclusion of the study?; and was the analytical method clearly explained and appropriate for the study. A tick symbol (✓) was used to show that an article met a criterion, while a negative symbol (X) indicated that the article did not meet a criterion. Each tick symbol represented one point, and each negative symbol represented 0, for a total of five quality assessment points for each article. Scores of 2 and

below were classified as low, 3 was moderate, and 4 and above were high (see Table 1 for quality assessment).

Data analysis and synthesis

The results are presented using a narrative approach because of the small number of studies represented in this study. The results were first summarised and then synthesised and adapted the approach originally described by Ramirez et al. (28). Specifically, the results were grouped into two categories of factors affecting access to healthcare: results that showed factors associated with barriers and facilitators of access to healthcare. Many of the studies in this review reported on various factors that hindered young informal workers from accessing healthcare (barriers to healthcare access). A few other studies reported on the factors that facilitated healthcare access. The heterogeneity in the outcomes and study designs of the included studies prohibited meta-analysis. Therefore, the result was presented in a narrative format.

Results

Study selection

The study selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guidelines (19). The search and screening stages are represented in Figure 1. After removing duplicates, the search yielded 1,015 unique studies screened using the inclusion/exclusion criteria. The majority ($n = 636$) of the studies were excluded at the title and abstract levels. A second-level screening was conducted, which identified and excluded 201 records, including unidentified duplicates, literature reviews, reports, and working papers. A further 161 records were excluded because they were published before the year 2000 ($n = 74$) and did not fit our definition of young people [including the one article that does not represent young informal workers ($n = 90$)]. Finally, a total of 14 studies were included in the total sample that are reported here.

Description of the included studies

The quality appraisal ratings and key descriptive information for each of the 14 studies included is presented in Table 1. Thirteen studies were rated high quality, two were rated moderate quality, and 1 study was assessed as being low quality (See Table 1). Following the data extraction and synthesis, the barrier factors to healthcare access were grouped into four coherent categories based on the four dimensions of access to healthcare (affordability, availability, accessibility, and acceptability); the facilitating factors were grouped into three categories (social networks, health insurance, and technology).

In terms of the study design adopted by the articles in this review, 53.3% ($n = 8$) employed a quantitative research design, 33.3% ($n = 5$) were qualitative, and 13.3% ($n = 2$) utilised a mixed-method approach (See Table 2). The majority ($n = 10$) of quantitative studies (including mixed methods) employed a cross-sectional and survey data collection method; the sample also included 1 quasi-experimental study. Among the qualitative studies, the three studies

TABLE 1 Quality assessment of studies included.

S/N	Criteria	Akazili et al. (11)	Sychareun et al. (7)	Webber et al. (8)	Salman et al. (26)	Natha Mote (22)	Namsomboon and Kusakabe (10)	Nam et al. (9)	Gichuna et al. (13)	Dartanto et al. (25)	Boateng et al. (12)	Ahmed et al. (23)	Dartanto et al. (24)	Barasa et al. (14)	Ganem dos Santos et al. (27)
1.	Are the aims and objectives clearly stated in the publication?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2.	Is the research design specified, and is it suitable for the research goal?	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3.	Is the research process clearly explained?	✓	✓	✓	✓	X	✓	✓	✓	X	✓	✓	✓	X	✓
4.	Is there sufficient data to support the interpretation and conclusion of the study?	✓	✓	✓	✓	X	✓	✓	✓	✓	X	✓	✓	✓	✓
5.	Is the analysis method clearly explained and appropriate for the study?	✓	X	✓	✓	X	✓	X	✓	✓	✓	✓	✓	X	✓
6.	Total score	5	3	5	5	2	5	4	5	4	4	5	5	3	5

TABLE 2 Description of studies included.

S/N	Author(s)	Year	Objective	Design	Sample size	Age (years)	Study Site	Types of informal workers
1.	Webber, G., Spitzer, D., Somrongthong, R. et al.	2012	To assess access to sexual and reproductive health services for migrant women who work as beer promoters.	FGD and Survey (Mixed-Method)	390	Mean age = 24.2	Cambodia, Laos, Thailand and Vietnam	Female beer promoters
2.	Salman et al.	2015	To assess the prevalence of chronic diseases and workplace physical trauma among low-income workers.	Cross-sectional Survey (Quantitative)	707	15–35	Karachi, Pakistan	Varied
3.	Akazili, J., Chatio, S., Ataguba, J. E. O. et al.	2016	To explore the factors affecting informal workers access to health care services in Northern Ghana	Focus Group Discussions (FGD) and in-depth interviews (Qualitative)	21	18 and above	Rural Eastern and Western Districts of Northern Ghana.	Hairdressers, head potters, farmers and bar attendants.
4.	Teguh et al.	2016	To examine why informal workers are reluctant to join the national health insurance even though the programme's benefits are very generous.	Survey (Quantitative)	400		Indonesia	Varied
5.	Natha Mote	2016	To examine the health status, occupational and environmental health hazards among ragpickers working in the dumping ground of Shivaji-Nagar and Govandi Slums of Mumbai, India.	Survey (Quantitative)	120	18 and above	Mumbai, India	Ragpickers
6.	Sychareun et al.	2016	To examine the interplay between the experience of informal work and access to healthcare.	In-depth interviews (Qualitative)	24	18 and above	Vientiane city, Laos People Democratic Republic	Female beer promoters.
7.	Barasa et al.	2017	This paper analyses the perceptions and experiences of informal sector individuals in Kenya concerning enrolment with the NHIF.	In-depth interview (Qualitative)	39	Not stated	Kenya	Varied
8.	Boateng, S., Amoako, P., Poku, A. A. et al.	2017	To analyse the factors associated with enrolment in and renewal and utilisation of the NHIS among migrant female head porters in the Kumasi Metropolis.	Survey (Quantitative)	392	15–35	Kumasi, Ghana	Head potters

(Continued)

(7, 13, 14) employed solely in-depth interviews (IDIs), 1 study (8) employed solely focused group discussions (FGDs), and 3 studies employed both IDIs and FGDs (9–11). The majority (*n* = 14) of the studies were conducted in developing countries. This did not come

as a surprise, given the report that shows that 93% of the world's informal employment is located in developing and emerging economies (29). In terms of geographical locations, the majority (*n* = 9) of the studies were conducted in Asian countries

TABLE 2 (Continued)

S/N	Author(s)	Year	Objective	Design	Sample size	Age (years)	Study Site	Types of informal workers
9.	Ahmed et al.	2018	To estimate the impact of a Community-Based Health Insurance (CBHI) scheme on healthcare utilisation from medically trained providers (MTP) by informal workers.	Quasi-experimental (Quantitative)	1,292	Not stated	Bangladesh	Varied
10.	Namsomboon and Kusakabe	2011	To examine women homeworkers' access to healthcare services in Thailand.	Mixed-methods (Survey, IDI, and FGDs)	415	15–35 (75%)	Thailand	Female homeworkers
11.	Dartanto, T., Halimatussadiah, A., Rezki, J. F. et al.	2020	This study aimed at exploring the critical factors that affect the compliance behaviour of informal sector workers (PBPU members) in regularly paying their insurance premiums.	Survey (Quantitative)	1,210	Not stated	Indonesia	Varied
12.	Fabiana Sherine Ganem dos Santos et al.	2020	To determine the prevalence of syphilis and other sexually transmitted infections (STI's) among waste pickers who worked at the open dumpsite.	Survey (Quantitative)	1,025	18 and above	Brazil	Waste pickers
13.	Gichuna et al.	2020	To highlight specific effects of COVID-19 and related restrictions on healthcare access for sex workers in informal settlements in Nairobi, Kenya.	In-depth interview (Qualitative)	117	16–33 (83%)	Nairobi, Kenya	Sex workers
14.	Tien Nam et al.	2020	This study aimed to understand the factors affecting access to health services among waste collectors in Hanoi, Vietnam.	In-depth interview and FGD (Qualitative)	49	Not stated	Vietnam	Waste collectors

(Bangladesh, Cambodia, India, Indonesia, Laos, Nepal, Pakistan, Thailand, and Vietnam). This was followed by studies in Africa ($n = 4$; Ghana and Kenya). Study in South America ($n = 1$; Brazil) was the least represented (see Table 2). In terms of urban/rural settings, 57% ($n = 8$) of the studies were carried out in urban communities, 14% ($n = 2$) of the comprehensive studies were conducted in rural communities, and 29% ($n = 4$) conducted in both urban and rural communities (see Table 2).

Ten informal working populations were represented in this review; they include female beer promoters, bartenders/attendants (Cambodia, Laos, Thailand, and Vietnam), head potters, farmers, and hairdressers (Ghana), female homeworkers (Thailand), rickshaw pullers, ragpickers, waste collectors (Brazil and India), sex workers (Kenya). Three studies (7, 10, 13) had female-only respondents.

The 14 studies under review had a considerable variation in sample size; the qualitative studies ranged from 21 to 49 respondents for the focused group discussions and 12 to 117 respondents for the in-depth interviews. In contrast, the quantitative studies had larger sample sizes ranging from 120 to 2,726. One quantitative study (22) did not have an adequate sample to justify its result (see Table 2).

Factors affecting access to healthcare among young informal workers

Barriers to access to healthcare

Several factors were shown to hinder access to healthcare services for informal workers across different study locations. For the sake of

this study, all the elements would be grouped under four dimensions of healthcare access (affordability, availability, accessibility, and acceptability) following the conceptual framework of access to healthcare (21).

Affordability of healthcare

Eight studies (8–13, 24) discovered affordability as one of the significant barriers to healthcare for young informal workers across diverse industries. Five studies (7–11) identified the cost of seeking formal healthcare as one of the problems young informal workers are unable to seek the healthcare they need. Sychareun et al. (7) and Akazili et al. (11) argue that informal workers are lower earners and, therefore, they may undergo financial distress in accessing healthcare. Two studies (8, 9) identified the direct cost of transportation as another component of affordability that hindered young informal workers from accessing healthcare because of the distance from where they live to the hospitals. Five studies (8, 9, 11, 12, 24) identified the absence of health insurance for young informal workers, leading to high out-of-pocket payments and high costs of healthcare. There was also evidence that other indirect affordability factors, such as long waiting time (9) and the loss of daily/weekly wages and jobs (7, 11), hindered young informal workers from seeking healthcare. Absence from work as a result of going to the hospitals may result in pay cuts or loss of jobs for these groups of people due to the long waiting time many experiences at the health centres (7).

Accessibility of healthcare centres

Five studies (8–11, 30) identified problems of accessibility as some of the barriers to healthcare among young informal workers. Two studies (8, 9) found that the distance to hospitals and travel time were limitations to how much informal workers could seek healthcare. As a result of the distance and travel time, particularly for those who reside in rural areas (30), many informal works result in obtaining services from informal drugstores closer to them (9). Two studies (8, 11) observed that the means of transportation was another factor. Because many informal workers lived outside of town, it was more challenging to frequently visit the hospitals or health centres due to bad roads (11) or less frequent public transport systems (8). As a result of low educational qualifications, many young informal workers lacked the knowledge or information related to navigating health systems (10). Their educational qualification also made it difficult to understand the complex billing system in many hospitals; as a result, many of them self-medicated if they had no one to support them (9).

Acceptability of healthcare

Four studies (7, 9–11). Three components of service acceptability were identified in the above four studies. The first one is the perceived poor treatment from health personnel. The formal healthcare centres were often seen as a place of last resort after self-medication and other sources of treatment proved futile (7). This was simply because these informal workers perceived that the healthcare officials would not warmly receive them because of their socio-economic status, particularly their level of income and education (7–9). The second component is the poor quality of healthcare informal workers receive. Two studies (7, 10) found that informal workers in Laos and Thailand perceived the quality of healthcare and the drugs they received as poor. This was associated with their report that the healthcare systems around them were not sufficiently developed (7). The third component

this study identified is the perceived cleanliness of the health centres. One study (8) found that informal workers refused to go to the health centres because of the perceived state of sanitation.

Availability of healthcare resources

Availability of service is measured as the opportunity to access quality healthcare service as and when needed (21). The concept of healthcare service availability includes healthcare workers' availability, medication stock, long waiting times, and equipment. Tien Nam et al. identified these five components of healthcare availability (infrastructure, human resources, medical equipment, and medicine) as barriers to healthcare service among waste collectors in Hanoi, Vietnam (9). Seven studies (7–9, 11, 13, 24) reported availability as one of the service barriers. The problems of availability were linked to the lack of available medical equipment (13), insufficient healthcare personnel, particularly doctors (9, 11, 13), and inconvenient opening and closing hours (13). Gichuna et al. found that female sex workers were denied access to sexual reproductive healthcare because there was no specialised equipment to provide the service they needed (13). However, this study was conducted at the peak of the Covid-19 pandemic, when the movement of goods and services was restricted (13). In Ghana and Vietnam, most informal workers live in the rural areas or the outskirt of towns, where there are no sufficient doctors or nurses to cater for the healthcare needs of the multitude of informal workers in those areas (9, 11). Finally, the opening and closing hours of the health centres were unsuitable for these young informal workers because many of them resumed very early to work or closed late at night after most hospitals or clinics had closed (7, 9, 11, 13). Absence during working hours puts them at risk of pay cuts or loss of jobs (7). In the case of female sex workers in Kenya, Covid-19 was the reason for the disruption in the opening and closing hours of the health centres (13). In sum, the availability of healthcare resources is a significant barrier to healthcare for young informal workers, majorly, supply side factors, such as the availability of doctors, equipment, medicines, and even the opening and closing hours of health centres are barriers to seeking healthcare for many young people in the informal sector.

Facilitators of access to healthcare

Two factors (social network and health insurance) that facilitate access to healthcare for young informal workers were identified from seven studies (7–9, 11, 12, 24, 31). Five studies (7–9, 11) found that social networks, such as friends, families and co-workers, facilitated entry into healthcare systems by lending or gifting cash to their peers, siblings, children or relatives who fell under this category. Not just money but social networks were instrumental in choosing the healthcare institutions they sought (7, 8, 11). Finally, Webber et al. (8), Nam et al. (9), Akazili et al. (11), and Teguh et al. (24) identified that being enrolled in the government's health insurance scheme was significant in overcoming the financial barrier of seeking healthcare.

Discussion

Summary of results

The primary aim of this systematic review was to identify, analyse and synthesise empirical evidence on the factors affecting the access

to healthcare of young people in the informal sector. In doing so we assessed 14 studies, to the best of the author's knowledge, making it the first and the most comprehensive systematic review to focus specifically on the access to healthcare for young people in the informal sector in developing countries. The relatively large body of evidence included in this review supports the conclusion that young people in the informal sector face significant barriers (affordability, availability of healthcare resources, accessibility of healthcare systems, and the acceptability of healthcare services) to healthcare. However, some factors, such as social networks and health insurance, if prioritised by policymakers in majorly developing countries, can improve young informal workers' access to healthcare.

Barriers to access to healthcare

This study identified several factors hindering healthcare access among young informal workers in developing countries. Each of these factors are grouped into the four dimensions of access to healthcare (affordability, availability, accessibility, and acceptability) utilising Peters et al. (21) access to healthcare framework. Although young informal workers are affected by each of these factors, we discussed based on the major hindering factors., that were identified as being responsible for young informal workers' failure to get health care.

Affordability of healthcare services

Several factors were linked to the problem of affordability. The most common affordability-related problem affecting access to healthcare for young informal workers was the cost of treatment (7–11). Healthcare financing for informal workers is mainly out-of-pocket; this is primarily because informal workers are largely excluded from social protection schemes such as health insurance. However, the situation is more challenging for young people than for older people. Unlike the older population, young people are hardly in trade unions or associations that can provide financial support for their healthcare needs. In addition, having and not having health insurance has been identified as a barrier or a pathway to overcoming financial barriers to healthcare services. In terms of promoting access to healthcare services, Tien Nam et al. identified the presence of health insurance as a potential facilitator of access to healthcare among informal waste collectors in Hanoi, Vietnam (9). A study by Ahmed et al. using healthcare utilisation as their variable for access to healthcare (23). The study found that healthcare utilisation among informal workers was significantly higher in the insured group (50.7%) than in the uninsured group (39.4%) (23, 32). Their regression analysis further reported that the regression analysis demonstrated that the community-based health insurance (CBHI) beneficiaries were two times more likely to utilise healthcare. While Ahmed, et al., Boateng et al., and Teguh et al., similarly identified that health insurance schemes were necessary facilitators for healthcare access in Ghana (12, 23, 24, 25). However, except in a few developing countries where health insurance is offered and subsidised for informal workers, many young informal workers are unable to obtain health insurance.

The second factor is linked to the income of young informal workers. One may argue that informal workers generally have low incomes. However, the problem of income is worse for young people than for the general adult population (33). As new entrants into the labour market with little or no skills and experience, young people are

usually at the lowest level of the income scale (33). Their earning is usually not enough to save and cover healthcare needs. This makes it more difficult for young people to access healthcare than other age groups of informal workers. Another factor is the cost of being away from work as a result of seeking healthcare (7, 8, 11). Absence from work is extremely costly for young informal workers since they lose their income for the duration of their absence and can even result in the loss of their employment if a prolonged medical treatment period is required, in addition to transportation expenses. Further, most informal employment sectors have no legal or formal social benefit arrangements, such as sick leave pays benefits when workers become ill (3). Therefore, absence from work to seek healthcare almost equates to a loss of income or job. This problem is common among young people because, unlike older people, they are more likely to be apprentices or employees with no autonomy (33, 34).

The last problem identified from the studies under review is that of transportation cost (7, 8, 11). The problem of affordability, either directly or indirectly, has been linked to the poor wages of young people in the informal sector (7–9, 11). This is evident in the case of young female beer promoters in Laos (7), head potters and hairdressers in Ghana (11) and female bartenders in Laos, Thailand, and Vietnam (8). This study's finding is similar to previous research, which found that disadvantaged populations had less access to healthcare services due to poverty or lack of financial capacity (21, 35). Most informal workers do not earn enough money to save or care for their health needs. As a result, it is not surprising that most of the studies in this review revealed that most young informal workers could not afford health care because they likely do not have much to cover extra expenses beyond their basic needs.

To overcome the affordability barrier, young informal workers relied on their social networks, such as friends, family members (parents, older siblings and relatives), neighbours, co-workers, customers and employers, to access healthcare (7–9, 11). Social networks provided instrumental support to young informal workers through lending or gifting cash to seek healthcare. Unlike a previous study (36) on social networks, and access that found that weak ties, such as members of associations and distant relationships, were more important for accessing resources, this study found that in the case of young informal workers, close social ties were the most important social relationships for accessing healthcare. For instance, Sychareun et al. and Webber et al. found that parents and peer networks were instrumental for young informal workers to overcome financial barriers to healthcare access (7, 8). Only one study (11) found that distant relationships, such as employers, were significant in providing financial resources to young informal workers who access healthcare. However, none of these studies measured how social networks can promote access to healthcare for young informal workers. The generalisation of social networks' influence on access to healthcare may be difficult based on contextual factors like ethnicity, religion, culture, and economic activities that can determine the extent of a social network–health relationship (37).

Availability of healthcare resources

According to the findings, the second most significant dimension of healthcare for young people is the availability of healthcare. Although the availability of healthcare (shortage of healthcare resources such as human resources, equipment, and medicines) is a dominant healthcare problem in many developing countries, the

problem is particularly significant for informal workers, particularly women (7, 8, 11). For example, young female bartenders and beer promoters in Thailand, Vietnam, and Laos DPR are hesitant to seek healthcare due to feelings of shame and fear following harassment and stigmatisation from their customers (7, 8). However, there were no nearby healthcare services tailored to young people's needs in such situations. This lack of available healthcare may result in even greater levels of fear, anxiety or depression, and even substances use as a coping strategy among young female informal workers.

A further problem for many developing countries is that healthcare personnel and equipment are very limited, leading to long wait times for treatments in many public hospitals (21). Those who cannot afford private medical care find this aspect especially challenging. This is particularly a concern for young informal workers because, as mentioned previously, absence from work often equates to a loss of income and sometimes loss of jobs. This can cause a considerable financial burden on families and lead to further poverty among young informal workers in developing countries. Furthermore, COVID-19 also exacerbated healthcare availability problems for young informal workers (13). The supply of other healthcare resources likely declined due to the high priority placed on COVID-19 resources. This led to fewer healthcare services for non-COVID-19-related issues (38, 39). In some cases, this has decreased the quality of care for those seeking treatment for other medical issues (13, 39). Furthermore, appointment wait times may have increased, causing further delays in treatment.

Acceptability of healthcare

The third dimension of access to healthcare that significantly affected the access to healthcare for young informal workers was acceptability. Based on the evidence from the studies in this review, the problem of acceptability can be viewed from two sides. On the one hand, the problem of acceptability was a supply-side problem; on the other, it was a demand-side problem. On the supply side, the attitude of healthcare workers and stigmatisation served as barriers to access healthcare for young informal workers (7–9, 11, 13, 14). First, young informal workers reported negative attitudes, such as neglect and insults from healthcare operatives towards them because of their socio-economic status. Furthermore, young female informal workers reported incidences of stigmatisation because of their jobs as bartenders or beer promoters (7, 8). They were perceived as sex workers and treated poorly (7, 8). These factors lead to demand-side factors such as fear and lack of trust and confidence in healthcare providers, which hinder many young people from seeking healthcare even when they can afford it (30). This can lead to delayed diagnosis and treatment of health conditions, resulting in poorer health outcomes. Additionally, young women may also experience social isolation due to their perceived status as sex workers, which can further compound their health and safety risks. Evidence from studies in low-and-middle-income countries suggests a prevalence of poor-quality healthcare, which is attributed to between 5.7 and 8.4 million deaths annually (32). However, the extent to which it affects the health of young informal workers was not stated in any of the studies included in this review. To overcome these challenges, young informal workers relied on peer networks to choose where to seek healthcare (7, 8). Peer networks were important in the healthcare-seeking behaviour of young informal workers. The choice of whether to seek care was not only based on the direct previous experience of young informal workers but also on the experience of their friends or colleagues. Studies have shown that young people rely on recommendations from friends for where to seek care because of confidentiality issues (30). To this end, peer networks can act as a support system that encourages young informal workers to seek out the healthcare they need. Additionally, these networks can provide information on the best place to seek care and ensure that young informal workers receive the treatment they need in a safe and secure environment.

Accessibility of health centres

Finally, the last major factor impeding young informal workers' access to healthcare was accessibility. Travel distance, time, and inadequate transportation (7, 8, 11) were the two biggest hurdles to geographical accessibility. While this is a concern for all informal workers in most developing countries, it is exacerbated for young informal workers due to the time away from work, which may result in income loss. This was especially noticeable among young informal workers who do not reside or work in urban areas (11), with sparse healthcare services and inadequate transportation infrastructure. According to Amoah and Peters et al., many developing nations encounter issues with the problems accessibility of healthcare services due to poor transportation infrastructure (21, 40).

Furthermore, COVID-19-induced inaccessibility was identified due to physical distancing measures implemented by governments to reduce the spread of the Coronavirus. Individuals could not travel out of town to obtain healthcare (41, 42). This made it difficult for many young informal workers in developing countries to receive the care they needed. To address this, telehealth services were introduced in many advanced countries to provide healthcare services remotely (43). However, for those in developing countries with limited capacity, especially for underprivileged populations like young informal workers, accessing healthcare remained a significant challenge. For example, female sex workers in Kenya face a significant challenge in travelling to the hospital to obtain sexual and reproductive healthcare due to the social distancing measures in Kenya (13).

Strength and limitation

To the best of the author's knowledge, this review is the first to systematically collate, analyse and synthesise empirical peer-reviewed evidence of different research designs on access to healthcare among young people in the informal sector. This study brings together factors affecting access to healthcare for young informal workers across different developing countries. Also, the included studies were rated from moderate to high, which strengthens the quality that can be drawn from the synthesised result. However, this study has some limitations. Our study also has difficulty capturing all groups' views, although access to healthcare remains a significant focus area for researchers and policymakers globally. Therefore, it is essential to note some of the limitations of this study. Most of the studies reviewed in this article are not nationally representative and pertain to a small population segment. Therefore, caution should be taken when interpreting the results of this study. There is a need for further research to understand whether these findings will be applicable to a wider population. We acknowledge that all relevant literature may not have been captured, as journals are known to favour papers based on

statistical significance; such papers may not have been represented here. Although the systematic review was thoroughly conducted and efforts were made to ensure the search strategy was as robust as possible, the success in capturing studies was also dependent on adequate indexing of studies within the databases. Finally, non-journal papers, unpublished works, and thesis were not included in this review. Such publications may shed light on the issues influencing young informal workers' access to healthcare and good health.

Policy implication

Through this systematic review, we have tried to investigate the major factors affecting young informal workers' health and well-being. We have also discussed how and to what extent such factors like social networks (social relationships) and health insurance impacted their life. The ultimate goal of researching access to healthcare is to provide policy recommendations for improving the population's health and well-being (44). Our findings suggest that governments in developing countries should not neglect the health needs of young informal workers as a significant stakeholder and contributor in the national economy. To achieve universal healthcare and to ensure healthy lives and well-being for all (SDG-3), governments in developing countries need to collaborate with NGOs and researchers in delivering healthcare services to young informal workers.

Future research direction

In some developing countries where national health insurance schemes do not protect informal workers, assessing this variable for them may be unrealistic. Therefore, future studies need to be moved beyond identifying the factors affecting healthcare access. Assessing the extent to which these factors help improve young informal workers' health is rather crucial. The findings of such investigations may benefit governments, researchers, policymakers and non-governmental organisations interested in improving young people's health, particularly those in the informal sector.

Conclusion

Our study findings suggest that factors connected with the affordability, availability, accessibility and acceptability of healthcare represent some of the barriers many young informal workers encounter in seeking healthcare. Affordability represented the most significant barrier to healthcare that young informal workers face due to increased out-of-pocket healthcare expenditure and low wages of young informal workers in developing countries. This finding suggests that subsidised health insurance should be extended to young

informal workers in developing countries. Such a policy, however, should be tailored to the needs of each country. Developing countries need additional investment to meet young informal workers' healthcare needs. Young people are the lifeblood of any nation, so an investment in their health is an investment in its national growth and development. Moreover, the findings suggest that informal sectors should be more regulated in developing countries to enhance labour rights standards and minimise the exploitation of young informal employees.

Further, our findings indicate that social networks and health insurance contribute to improved health outcomes. While previous studies provide evidence on the factors that affect access to healthcare for only a few groups of informal workers, it remains unclear if these factors can be generalised across all young people in the informal sector. Also, the extent to which these factors affect the health of young informal workers remains unknown. The findings from this review point to significant gaps in access to healthcare literature and suggest areas of future research directions.

Author contributions

AOO was responsible for the concept development and initial manuscript drafting. TK was responsible for the search. AOO, TK, and MA were responsible for the data analysis and synthesis. MA reviewed the manuscript. 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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Preventive health examinations: protocol for a prospective cross-sectional study of German employees aged 45 to 59 years (Ü45-check)

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Objective: Early identification of health-related risk factors is of great importance for maintaining workability. Screening examinations can help to detect diseases at an early stage and provide more needs-based recommendations. This study aims (1) to assess the individual need for prevention or rehabilitation based on preventive health examinations compared to a questionnaire survey, (2) to assess the results of the preventive health examinations compared to the Risk Index − Disability Pension (RI-DP), (3) to assess the results of the questionnaire survey compared to the RI-DP, (4) to assess the general health status of the sample (target population>1,000) in German employees aged 45−59, (5) to identify the most common medical conditions. A further study question aims, and (6) to investigate the general health status of the specific occupational groups.

Methods: Comprehensive diagnostics including medical examination, anamnesis, anthropometric measurements, bioelectrical impedance analysis (BIA), handgrip strength, resting electrocardiogram (ECG), resting blood pressure, pulse wave velocity (PWV), and laboratory blood analyses added by a questionnaire are conducted. The research questions are analyzed in an exploratory manner.

Results and conclusion: We expect that the results will allow us to formulate recommendations regarding screening for prevention and rehabilitation needs on a more evidence-based level.

Clinical Trial Registration: DRKS ID: DRKS00030982.

KEYWORDS

screening, prevention, rehabilitation, medical health examinations, disability pension, Ü45-check

Introduction

Demographic change is a topic that is not only being discussed in Germany today but has been known for decades. High-birth-rate cohorts such as the baby boomers will retire or take early retirement in the near future. The shrinking population in Germany and the demographic aging are increasing challenges for the healthcare system and the social insurance system (1).

The COVID-19 pandemic may have led to a rise in early labor cessation in the baby boomer generation, which represents an additional challenge (2).

Various diseases can lead to incapacity for work. Some of the risk factors can expand unnoticed over decades, namely an unhealthy diet, smoking, excessive alcohol consumption, and a lack of physical activity. Overweight and obesity numbers have risen in industrialized countries in recent years (3). Due to the high number of risk factors, specific prevention and rehabilitation measures should be developed to prevent and reduce diseases (4). Screening examinations are encouraged to determine an individual's risk of developing diseases. In order to find out which program or therapy is individually appropriate, health checks should be performed. It is important that public healthcare institutions provide information about screening examinations and ensure access (5). The focus should be on education regarding the early detection of diseases so that individuals are able to evaluate the benefits and participate in screening examinations. It is important to target asymptomatic individuals to detect possible diseases at an early stage (6, 7) as non-communicable diseases, like cardiovascular diseases, are the leading cause of mortality globally (8) and account for 40% of all deaths (9). Screening examinations could assess the risk of developing cardiovascular disease in Germany (6).

For a feasible and effective screening, a comparison of different screening models is required. While screening examinations were once dismissed as unimportant because of their little yield, in recent years they have moved more into focus again. The reason for this is that screenings are being developed in a more targeted manner, such as precisely for pre-symptomatic individuals or certain age groups (10).

The study 'Ü45-Check' addresses interests and questions from the fields of politics, medicine, and science. In 2016, a pension law (11) was passed in Germany that allows a more flexible entry into retirement, following the Scandinavian model (12). Three political parties (Social Democratic Party of Germany (SPD), Alliance 90/The Greens (Bündnis 90/Die Grünen), and Free Democratic Party (FDP)) have formed a coalition in Germany in December 2021. In the coalition agreement for 2021–2025 (13), a paragraph on prevention and rehabilitation has been written, stating that healthier working should be the focus of pension policy. The associated principle 'prevention before rehabilitation before retirement' promises simplified access to prevention and rehabilitation programs. Following this, the present study is listed in the coalition agreement for 2021–2025 on page 58 (13).

The challenge of simplifying access to prevention and rehabilitation programs is of particular interest to public health reducing sick leave and disability pensions potentially leading to higher costs for the social insurance systems, such as the German Pension Fund (GPF) (14, 15).

To gain further insight into the characteristics of disability pension applicants, a risk level prediction index was developed in a previous research project. Bethge et al., 2011 (16) developed the Risk Index – Disability Pension (RI-DP). They identified variables of prognostic

relevance for disability pension in the register data of the GPF and constructed a risk index for work disability that is applied in the present study.

The primary aim of this study is to assess the need for prevention or rehabilitation based on preventive health examinations compared to a questionnaire survey by another research group (17, 18). As secondary aims, we, first of all, want to examine the influence on relationship between the medical examinations, the questionnaire, and the RI-DP on a disability pension. As further secondary aims, we are interested in assessing the general health status of the sample of German employees aged 45–59. Thereby, we are interested in the most common medical conditions, the health status of the specific occupational groups, and the need for rehabilitation.

Primary study question

1. Are there differences in the assessment of the need for prevention or rehabilitation based on the preventive health examinations compared to accessing the need for preventive or rehabilitation measures by a questionnaire survey?

Secondary study questions

2. Is there any relation between the results of the preventive health examinations and the RI-DP Index (traffic light systems)?
3. Is there any relation between the results of the questionnaire survey and the RI-DP Index (traffic light systems)?
4. What is the general health status of the sample of German employees aged 45–59?
5. Which diseases are most common in the sample?
6. What is the general health status of specific occupational groups?
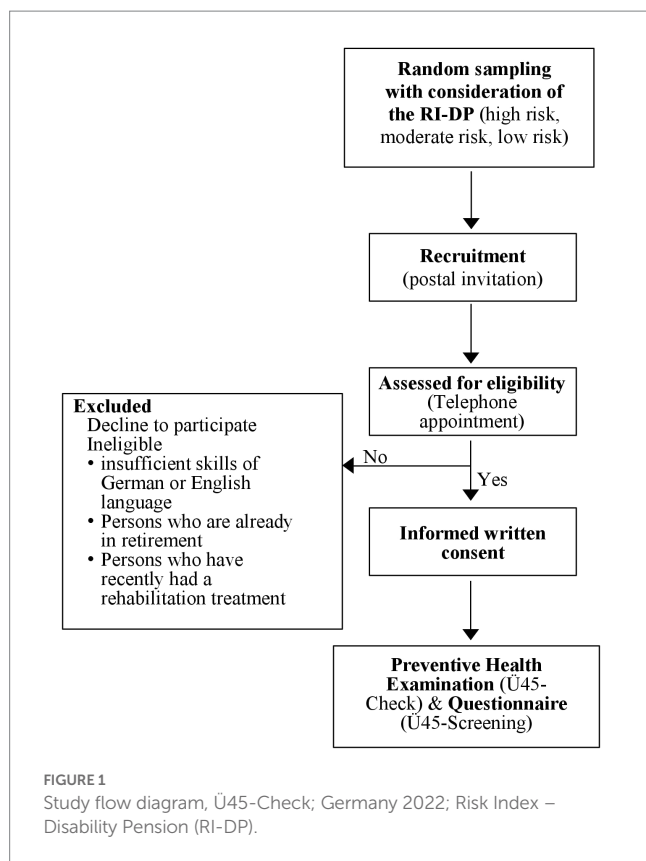
Methods/study design

Study design and population

This study is designed as a cross-sectional trial to investigate the implementation and evaluation of preventive health examinations offered to adults aged 45 to 59 years in Berlin and Brandenburg, Germany. Administratively, all persons insured by the GPF who were between 45 and 59 years old and living in Berlin or Brandenburg in June 2021 were identified in the GPF Registers and allocated to one of three groups in terms of risk for work disability [see *Risk Index – Disability Pension (RI-DP)*]. The subjects (target population > 1,000) will be randomly selected from each of the three groups and will be invited to attend the preventive health examination (Ü45-Check) in the following two consecutive calendar years (2021 to 2023) (Figure 1).

Inclusion criteria

- Insured persons of GPF, residence in Berlin or Brandenburg
- Age of 45 to 59

FIGURE 1
Study flow diagram, Ü45-Check; Germany 2022; Risk Index – Disability Pension (RI-DP).

TABLE 1 Ü45-Screening questionnaire.

	Measurement	Technical information
Questionnaire	**Ü45-Screening** Work ability Mental health Functional ability Coping behavior Sports and exercise behavior	IPAD 6th generation, Apple, U.S.

A person has a high risk of disability pension if the RI-DP is ≥60, a moderate risk is <60 und ≥ 50, and a low risk is <50 (16, 19).

In our study, the RI-DP is collected and considered during recruitment. It does not influence the study participation or non-participation. Physicians and study participants do not have any information about the respective index value (of the subject), only the project management does.

Exclusion criteria

- Insufficient skills in German language or English language
- Persons who are already in early retirement
- Persons who have recently had a rehabilitation treatment

Setting

The preventive health examinations are performed in the outpatient clinic of the Department of Sports Medicine, Charité – Universitätsmedizin Berlin/Humboldt-Universität zu Berlin. Charité – Universitätsmedizin operates as an independent contractor within the public health service and is remunerated based on a combination of fee-for-service.

Recruitment and invitation

All subjects will receive a postal invitation from the GPF including information about the objectives of the Ü45-Check health examination. Subjects can voluntarily contact Charité – Universitätsmedizin Berlin by phone or email to schedule an appointment. A suggested appointment time is provided. The scheduled time may be accepted, modified, or rejected via phone or email. Three months after the postal invitation, the subjects receive a letter for the evaluation of the Ü45-Check. The evaluation is part of another research group.

Questionnaire (Ü45-screening)

Before the health examination, subjects are asked to answer a web-based questionnaire, which may be completed in approximately 10 min. The questionnaire was developed by another research group in 2019, as part of the Ü45-Check (17, 18). The questionnaire includes five dimensions adapted from already established questionnaires, which have been proven to help identifying an already existing limitation of the ability to work or predict a hazard. The questions relate to dimensions of workability, mental health, functional ability, coping behavior, and sports and exercise behavior (Table 1). Items were reused from the Work Ability Index (WAI) (20), SIMBO (21), PHQ-4 (22), IRES-3 (23), and General Practice Physical Activity Questionnaire (GPPAQ) (24). The questionnaire can be found in Supplement S1. Subjects are informed about the opportunity for responding to the questionnaire together with study staff if support is needed for any reason.

Risk index – Disability pension

The study of the RI-DP was designed as a case–control study of the GPF using data from 8,500 men and 8,405 women. Independent samples (control group) were used to validate their models. The information revealed by that index can be used to enhance the provision of rehabilitation programs. The RI-DP can be calculated based on secondary data for the 3 years preceding the reference year.

The questionnaire is evaluated using a point system, accordingly, different values depending on the answer to each question, and dimensions are evaluated separately and weighted differently. Further details can be found here (17, 18). Three domains are categorized in the questionnaire evaluation: no action needed, prevention program suggested, and rehabilitation program suggested. Accordingly, 'need for action' (e.g., rehabilitation program suggested in the dimension of 'workability') is present when the score reaches more than half of the possible points (≥ 7 of 12 possible points). Prevention program in the dimension of 'work ability' is recommended if the score reaches 1/3 of all possible points (≥ 4 points) (17, 18).

Preventive health examination

The health professionals at Charité – Universitätsmedizin Berlin will perform the clinical examination. The examination in total takes approximately 120 min including the following diagnostics: Anthropometric measurements, bioelectrical impedance analysis (BIA), handgrip strength, systolic and diastolic blood pressure (SBP and DBP) (25), resting electrocardiogram (ECG), and pulse wave velocity (PWV) (26). The subjects will wear underwear during instrumental diagnostics.

Details about the diagnostics and measurements are given in Table 2.

In the following consultation with a physician, a careful anamnesis regarding the relevant medical history is conducted. As most days missed at work are due to cardiovascular, orthopedic, or mental illness, former medical reports are screened for relevant cardiopulmonary, orthopedic, or psychosocial diseases or risk factors. Furthermore, medical needs and current health problems addressed, giving advice on further treatment and evaluation. In addition information about regular exercise/physical activity, health-relevant habits, as well as a healthy diet, is given.

The physical examination will focus on the cardiovascular system, lungs, and abdomen. The blood analyses will be taken under fasting conditions. These include screening parameters for diabetes, lipid profile, inflammatory markers as well as liver enzymes, and thyroid hormones. In addition, a urine sample is screened for proteinuria, hematuria, leukocyturia, and other abnormal parameters (Table 2).

Assessment of body composition

A non-invasive bioelectrical impedance analysis (BIA) will be conducted to estimate body composition. Well-trained study staff will perform the measurement according to the standardized procedure. Subjects will be instructed to abstain from caffeine and alcohol for 24 h, and exercise for 12 h before testing according to published guidelines for BIA (27). Multiple frequencies at 5, 20, 250, and 500 kHz will be used to measure intracellular and extracellular water separately. The subjects will be measured under laboratory conditions standing barefoot, in underwear, and without wearing jewelry on the device. With abducted arms 15° and legs 45° apart, they will hold a hand electrode with a contact of all 10 fingers while heels and forefeet will be placed appropriately on the foot electrode. Then, an alternating current of 250 mA of intensity will be applied to measure the impedance of the arm, trunk and leg muscles. Whole-body resistance will be calculated as the sum of segmental resistance

TABLE 2 Measurements in preventive health examination Ü45-Check.

Clinical measures	Measurement	Technical information
Anthropometry	**Height (cm), Weight (kg)** Body-Mass-Index (BMI) (kg/m^2)	Seca 274 Stadiometer, Seca, Germany
	Waist (cm), Hip (cm) Waist-to-Hip-Ratio (WHR) (Waist cm/Hip cm)	Seca 201 measuring band, Seca, Germany
Body composition	**Bioelectrical Impedance Analysis (BIA)** Percent body fat (PBF), Fat free mass (FFM), Visceral fat area (VFA), Total body water (TBW), Intracellular water (ICW), Extracellular water (ECW), Phase angle (PhA)	InBody 770, Inbody, South Korea
Handgrip strength diagnostics	**Handgrip Strength** (2 times each hand)	Hand dynamometer Lite, Baseline Evaluation Instruments, Germany
Cardiovascular diagnostics	**Twelve-lead Resting Electrocardiogram (ECG)**	Custo cardio 400, Custo med, Germany
Vascular diagnostics	**Blood Pressure (BP)** Systolic blood pressure (SBP) Diastolic blood pressure (DBP)	Classic III Stethoscope, 3 M Littmann, U.S.; boso med I, BOSCH + SOHN GmbH, Germany
	Pulse Wave Velocity (PWV) **Pulse Wave Analysis (PWA)**	Vicorder, SMT, Germany
Anamnesis	Chronic or current symptoms, medical history, family history, medication, dietary habits/supplements Cardiovascular risk factors, activity and training	IPAD 6th generation, Apple, U.S.
Cardiovascular examination	Cardiac examination Pulmonary examination Abdominal examination Peripheral vascular Examination	CORE Digital-Stethoscope, 3 M Littmann, U.S.
Blood sampling and analyses	**Blood Analyses** Blood cell and differential cells count, electrolytes, C-reactive protein (CRP), liver enzymes (GOT (AST), GPT (ALT), gamma-GT), blood lipid levels (total cholesterol, HDL-cholesterol, LDL-cholesterol and triglycerides), renal function parameters, ferritin, fasting glucose, Glycosylated hemoglobin (HbA1C), thyroid-stimulating hormone (TSH), urine test strip	

(right arm, left arm, trunk, right leg, left leg). The BIA with InBody 770 (Seoul, Korea) has been validated by dual-energy X-ray absorptiometry (28). In normal and overweight adults, multiple frequency BIA underestimated the percentage of body fat within the precision of the BIA instrument (2%) (27, 28).

Assessment of handgrip strength diagnostics

The handgrip strength diagnostics is measured by a research assistant using a hand dynamometer (Baseline Evaluation Instruments, Germany) (29). Subjects are encouraged to squeeze a hand dynamometer as hard as possible using one hand. Handgrip strength is measured in a seated position with the elbow flexed at 90°, adjacent to the torso, and the thumb facing upward. Each hand is tested twice, alternating hands between trials with a 1-min rest between tests on the same hand (30).

Assessment of (cardio) vascular diagnostics

A Twelve-lead resting electrocardiogram (ECG) (Custo Cardio 200 Saug-EKG, Custo med GmbH, Ottobrunn, Germany) is performed.

First, the blood pressure is measured on both arms using the device (Vicorder, SMT Medical Technology GmbH, Germany). Then the pulse wave analysis is performed on the right upper arm, while the cuff is inflated to the diastolic pressure. In preparation for the PWV examination, a standard cuff is placed at the upper thigh on the right leg. Subsequently, a special collar is placed at the lateral right side of the neck over the common carotid artery region.

Traffic light system

Immediately after the Ü45-Check, the subject's health condition is assessed by physicians in a traffic light system. The study physician determines the health status based on the medical history and the examination results, but without knowing how the result of the questionnaire (Ü45-Screening) turned out. The subjects receive the results of each measurement and overall assessment of their health condition. Further examinations are needed and recommendations are offered stratified by the risk profile of the individual (Figure 2).

Statistical methods

All analyses will be conducted in an explorative setting. In the first step, a descriptive analysis will be performed summarizing all variables with absolute and relative frequencies for categorical variables, and means and standard deviations for continuous variables. Based on the primary study question, the hypothesis is that the assessment based on preventive health examinations differs from the assessment according to the Ü45-questionnaire. Hence, for the primary endpoint, the score according to the Ü45-Screening questionnaire will be evaluated first. Afterward, the results of the classification of patients into green, yellow and red based on the Ü45-Screening questionnaire are compared with the classification according to the physician's

assessment. Therefore a Stuart-Maxwell test will be used to test for marginal homogeneity and a weighted kappa coefficient using linear weights will be calculated. In the second step, the differences between the results based on the Ü45-Screening questionnaire and the medical assessment will be visualized using boxplots and histograms for all variables based on the clinical examination and the questionnaire, respectively. In addition, these variables are used to build two ordinal regression models, one that uses the physician's assessment as the dependent variable and one with the assessment by the Ü45-Screening questionnaire as the dependent variable. In each case, the green category is used as a reference. The two regression models are compared to determine the factors influencing the various ratings. Secondary aims (2) and (3), which aim to compare the assessment by means of the Ü45-Screening questionnaire and the medical assessment with the RI-DP index, respectively, will also be assessed by visualization for all variables using boxplots and histograms. Since the RI-DP index measures a different outcome from the assessment by the Ü45-Screening questionnaire and the medical assessment, a statistical test will not be used.

In order to assess the general health status of the sample, the variables of the anamnesis and the clinical examination are of main interest. Those variables are analyzed descriptively with absolute and relative frequencies for categorical variables, and means and standard deviations for continuous variables. In addition, this is also conducted as a subgroup analysis for different occupations. In order to assess which diseases are the most common in the sample, the absolute and relative frequencies of each disease are calculated and compared.

If missing values are present, their structure is analyzed and based on this, multiple imputation is considered.

Ethics approval and consent to participate

Ethics approval was obtained by the "Ethics Committee of the Faculty of Culture, Social and Educational Sciences, Humboldt-Universität zu Berlin" on August 20, 2020 (reference number: HU-KSBF-EK_2020_0010). The work described is carried out in accordance with the Declaration of Helsinki for experiments involving humans. All subjects are informed by the study staff about the study procedure, subsequent data storage, and confidentiality and pseudonymity regarding the data. Written informed consent is collected from all subjects that the study center is allowed to use the data for research analyses and publishing the data.

Trial registration and status

The trial was registered at the German Clinical Trials Register (DRKS-ID: DRKS00030982). Retrospectively registered December 27, 2022, https://drks.de/search/de/trial/DRKS00030982.

Recruitment of participants started at June 16, 2021 and will last until March 31, 2024. Until now (April 2023), 660 participants were successfully recruited and screened.

Discussion

The outcomes of the Ü45-Check study comprise different aspects of health-related risk factors. The medical check-up can detect

FIGURE 2
Study flow diagram, Ü45-Check Traffic light system; Germany 2022.
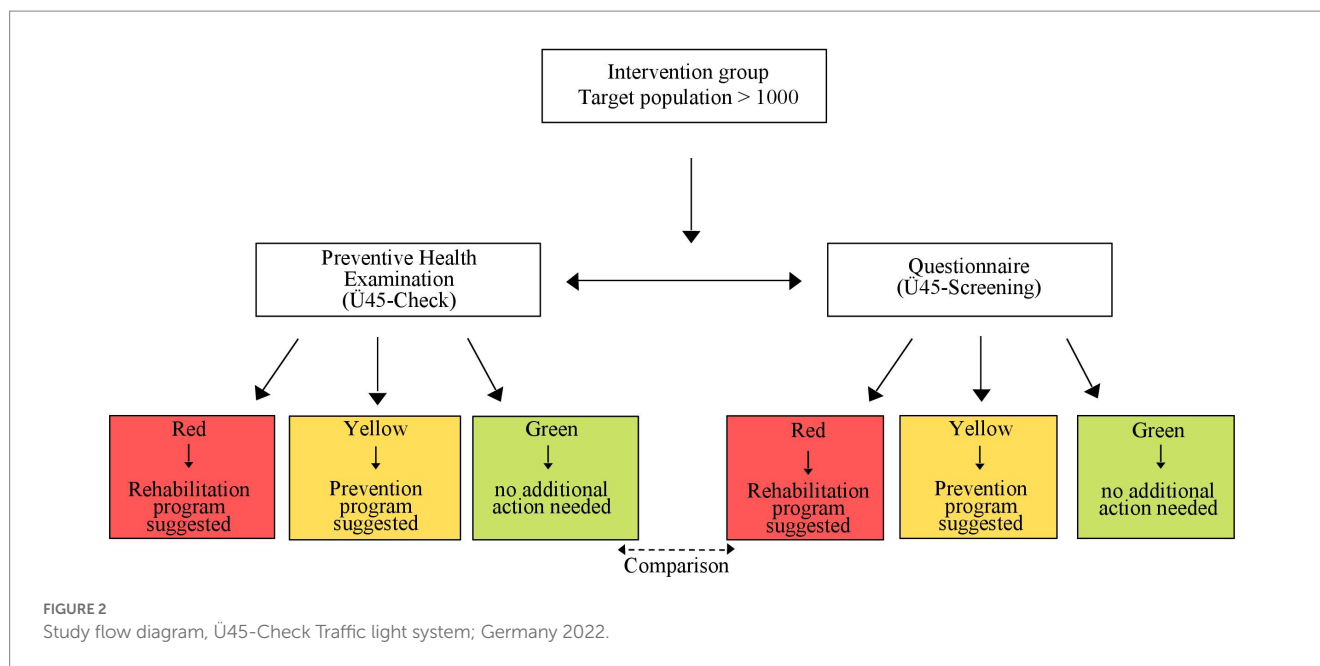
subclinical diseases and risk factors and reveal impairments ahead of time (5, 6, 31, 32). The Ü45-Check is based on available evidence on screening and preventive health examinations, closely aligned with the healthcare system in Germany. The study has been designed to develop a screening examination. The long-term goal of the federal government in Germany is to implement a screening examination in primary care. The evaluation of this screening method is part of another research project.

A screening program has the potential to label an asymptomatic person as a patient. Being labeled with a disease could have adverse effects, e.g., anxiety, worries, or panic attacks (33). Krogsbøll et al. (34) found in a meta-analysis that the majority of general health checks had no positive effect on morbidity, mortality and absence from work. A critical analysis reveals that the meta-analysis includes articles from the year 1963–1999 (34, 35). It is important to develop further studies and collect new data, considering demographic change and digitalization. Mortality as a parameter is not a sufficient criterion for the impact of health examinations, e.g., quality of life should be assessed (31). Since then, the working environment and leisure activities has changed completely. Obesity and the metabolic syndrome have increased over recent decades, which has become a growing and worldwide issue (36). Globally, social media screen time and game console screen time are on the rise. Living a sedentary lifestyle is a risk factor for various diseases.

There are also studies that have come to a different conclusion. A health check-up can have beneficial psychological and physical effects on the individuum. Health consciousness can be strengthened through a screening examination, which can lead to individuals being more motivated to be physically active and eat healthier (37). A healthier lifestyle leads to a better quality of life. Preventive measures that address participants' personal health practices are beneficial and have an influence on the participant's future health. Patients should be informed about health risks and be involved in the decision-making process of possible preventive measures (38). Studies related

to prevention examinations have shown that the level of psychological stress induced by screening is short lasting (39).

Prevention and Rehabilitation programs can be cost-intensive in the short term, but they are beneficial to the healthcare system in long term by addressing diseases sooner. A European model study showed that a health check assessing vascular diseases would be cost-effective in the six countries included (Denmark, France, Germany, Italy, Poland, and the United Kingdom) (40).

Another aspect is that non-participation in screening examinations is a well-known problem (41). The problem is that the need for lifestyle intervention of people who do not participate in preventive screening cannot be identified. Furthermore, it can be assumed that subjects that participated in the study might have had medical needs and therefore replied to the invitation more often than healthy individuals did (6).

Strengths

Early detection of risk factors is related to a better outcome (32, 42, 43) and can potentially prevent the manifestation of associated diseases or secondary complications. Not only is this important to prevent high costs for the social system, but we also suspect that the results of a comprehensive check-up had a health benefit for the individual (44).

The individual examinations of the Ü45-Check were carefully selected, on the one hand, to get a significance of the results and on the other hand that it can be carried out from an economic point of view in other institutions, like resident physicians. Key strengths of the Ü45-Check include the use of standardized methods to assess body composition and the use of previously validated measurement procedures [e.g., vascular diagnostics and handgrip strength diagnostics (26)]. Handgrip strength is well established as an indicator of muscular function, particularly among older adults (45). In this context, the measurement of handgrip strength is gaining importance

as a screening tool. A low skeletal muscle mass leads to an impairment of physical functionality and quality of life (46). Several studies also showed an association between decreased handgrip strength and increased mortality and hospitalization rates, so it is already being used in geriatric assessment (46–48). Handgrip strength can be recommended as a screening for identifying patients at risk of poor health status (49, 50). Furthermore, the PWV is a marker of aortic stiffness and enables a noninvasive measurement and analysis of the cardiovascular system. The association with cardiovascular risk is well-established in adults (51, 52).

Another strength is that the sample size also allows for more extensive statistical analyses (such as the analysis of factors influencing the various assessments using an ordinal regression model).

Limitations

Self-selection is connected to health consciousness, a state of being aware while willingly engaging in health-promoting activities, behavior, and lifestyle. A risk of bias could be that people who feel worse may have been more likely to accept the invitation for the Ü45-Check. However, it would also be possible that individuals with more risk factors may tend to choose not to attend preventive medical check-ups. The RI-DP could enable an active strategy to enhance participation in check-ups. The study design is a cross-sectional study, so it cannot be ascertained whether the participants accepted the recommendation for prevention or rehabilitation. However, a follow-up is planned and requested in the informed consent.

By considering the RI-DP in our study we have a selection bias. Therefore study question four, reflecting the general health status of the sample of German employees aged 45–59, cannot be answered for the general population.

Conclusion

The results of the Ü45-Check program, which is being conducted on behalf of the federal government, will provide a scientific basis that is important for primary health care.

Collaboration among a variety of organizations/professionals within an organization is useful to ensure successful screening programs (53).

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 Ethics Committee of the Faculty of Culture, Social and Educational Sciences, Humboldt-Universität zu Berlin. The patients/participants provided their written informed consent to participate in this study.

Author contributions

Funding

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.2023.1076565/full#supplementary-material

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Tolerance of immersive head-mounted virtual reality among older nursing home residents

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Introduction: Virtual Reality (VR) is a tool that is increasingly used in the aging population. Head-Mounted Displays (HMDs) are stereoscopic vision devices used for immersive VR. Cybersickness is sometimes reported after head-mounted display (HMD) VR exposure. Cybersickness severity and anxiety state reflect VR low tolerance. We aimed to evaluate HMD VR tolerance among older nursing home residents through cybersickness and anxiety state.

Methods: A total of 36 participants were included in this preliminary study, 33 of whom (mean age: 89.33 $\pm$ 5.48) underwent three individual HMD VR sessions with three different contents. Cybersickness occurrence and severity were scored by the Simulator Sickness Questionnaire (SSQ) after each session. Anxiety state was assessed by the State−Trait Anxiety Inventory form Y-A before and after each session. Anxiety trait (using State−Trait Anxiety Inventory form Y-B) was also evaluated before and after the experiment. In total, 92% (33/36) of patients completed all three sessions, of which 61% (20/33) did not report any cybersickness symptoms (SSQ = 0). Six participants reported significant cybersickness (defined by an SSQ score ⩾10) in at least one session.

Discussion: Only two participants stopped the study after the first exposure because of cybersickness. Age, cognitive function, anxiety trait, and well-being were not associated with cybersickness. The mean anxiety state decreased significantly from pre- to post-session. This immersive HMD VR experience was well tolerated among nursing home dwellers. Further larger studies in this population aiming to identify CS determinants are needed in order to use HMD VR on a standard basis.

KEYWORDS

older adults, virtual reality, tolerance, cybersickness, anxiety

1. Introduction

Populations around the world are aging (1), and most older adults suffer from at least one chronic condition (2). Chronic diseases lead to loss of autonomy (3), lower quality of life (4), and institutionalization (5).

Thus, innovative interventions are needed to promote a better quality of life. Virtual Reality (VR) is growing in the gerontology field (6). VR uses computer science (hardware and software)

to simulate virtual environments (7). Compared to traditional displays, such as computer monitors, Head-Mounted Displays (HMDs) isolate the user from the surrounding environment, offer stereoscopic vision, and adjust visual information to the user's head movements. HMDs mainly cover two major senses (sight and hearing), increasing the user's immersion (8). VR software can greatly vary in design and content (8). The typology of VR content includes 360° videos or photographs, which typically offer high realism. 3D-modeled environments may have varying levels of detail, from highly realistic to minimalist.

VR offers several advantages for healthcare, such as realistic perceptions and reactions, which optimize the patient's performance (9), motivation, and adherence to rehabilitation (10). On the other hand, Cybersickness (CS) can occur in 60 to 95% of users following exposure to VR with HMDs (11). CS is VR's most frequent side effect. Symptoms include nausea, vomiting, dizziness, vertigo, headache, loss of concentration, increased fatigue, and in extreme cases, complete incapacitation (12, 13). CS varies from one interface to another. CS in HMD VR tends to be more frequent and severe compared with other types of VR interfaces (i.e., large screen, CAVES, etc.) (14). In fact, it was found that motion sickness symptomology correlated (at post-test) with self-reported claustrophobic anxiety, probably due to the "imprisonment" of the head (15, 16). CS is significantly associated with anxiety state during exposure, which compromises well-being and leads to intolerance (17–19). Anxiety trait, a general tendency to be more anxious in various situations, is the most often investigated personality trait in relation to CS (20). Older adults' tolerance of VR varies substantially, depending on the content and the subject (see (8) for a review), thus impacting the user's experience and limiting VR application (21).

Despite its numerous uses in geriatric patients [cognitive training (22), physical rehabilitation (23), and mental health and affective disorders (24)], few studies have investigated VR tolerance in institutionalized adults. Considering the high risk of CS in a frail population, evaluation was found to be of interest in order to ensure the safety of the use of VR technology. Thus, the aim of this preliminary study was to evaluate (i) an immersive HMD VR program's tolerance, taking into account CS and anxiety, and (ii) its effect on the well-being of dependent nursing home residents as well as their reported experience.

2. Materials and methods

2.1. Participants and variables

In this interventional multicentric study, 36 participants were recruited from eight nursing homes in Paris, France from July 2021 to January 2022. Inclusion criteria were 75 years of age or older and a Mini-Mental State Examination (MMSE) (25) score of ≥20/30 (the higher the score, the better the cognitive function). To assess this cognitive state, a consensual French version of the MMSE (26) was used. Non-inclusion criteria were major visual impairment, history of epilepsy, orthostatic hypotension within the previous 3 months, psychiatric disorders (Schizophrenia, dissociative disorders, borderline states, paranoia), vestibular or cerebellar syndromes, and the following medications: neuroleptics, tricyclic antidepressants, and antiparkinsonian drugs.

2.2. Procedure

2.2.1. Ethics statement

Each participant provided written informed consent for the procedure. The study was approved by the French Ethics Committee East II (2020-A00377-32). The protocol was registered on ClinicalTrials.gov under the reference NCT04365829.

2.2.2. Participants

Participants' age, MMSE, and gender were collected. A total of 33 older adults were included out of the 36 who were screened. The mean age was 89.33 years old ±5.48, and 72.7% (n = 24) were women. The men's age was (mean ± standard deviation) 87 ± 5.17 and they had an MMSE score of 26.22 ± 2.91. The women's age was 90.21 ± 5.34 and they had an MMSE score of 25.13 ± 3.14.

One participant dropped out after the first session due to a lack of motivation. Two participants (mean age 88.5 ± 2.12 and mean MMSE 29 ± 1.41) refused further participation during the first session because of VR intolerance (Figure 1).

2.2.3. HMD VR exposure

Each participant underwent three individual VR sessions (S1, S2, S3) within a week (Figure 1). Each session (7-min exposure) took place individually in a quiet room. VR sessions were conducted using the Lumeen[1] software, which allowed the session to be controlled and monitored with a digital tablet, installed on a Huawei[2] Mediapad T5 tablet and a Pico G2 4K[3] HMD.

The immersive experiences consisted of 7-min 360° videos selected from Lumen's catalog. Participants watched only one of the following VR scenes per session: (a) Forest Through the Seasons, a 360° animation film (pre-rendered 3D graphics) in a cartoon style showing the changes of a forest landscape, (b) Animals of the World, a 360° live-action film of animals in the wild, and (c) The Grand Canyon, a 360° live-action film of a visit to the Grand Canyon (Figure 2). The virtual environment projected in the headset was coupled to the participant's head movement. They had no monitoring tool allowing them to start or stop the VR environment and no other possible interaction. The scene sequence was randomized by drawing at each session.

2.2.4. Outcomes

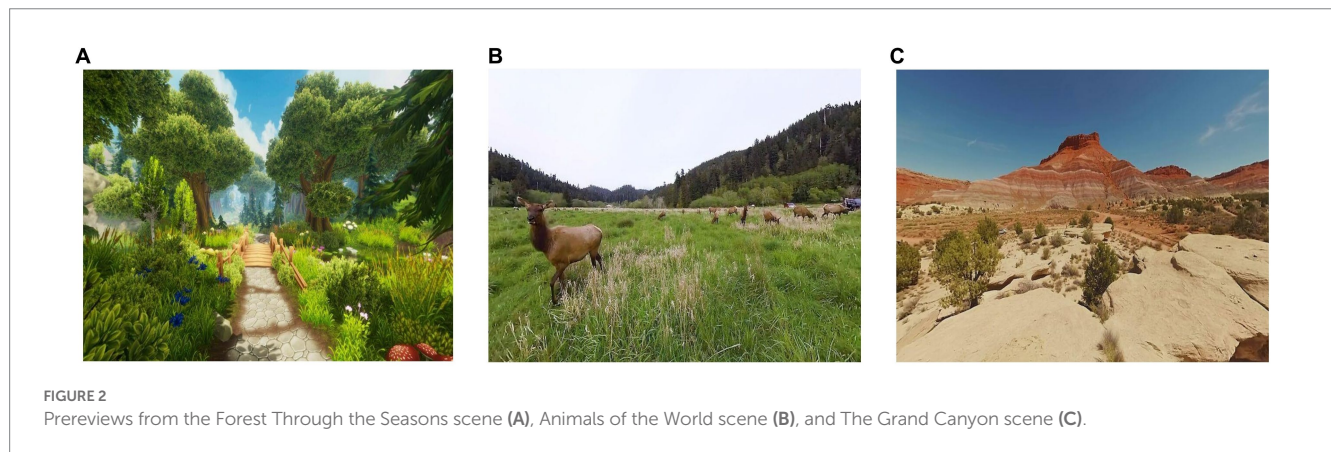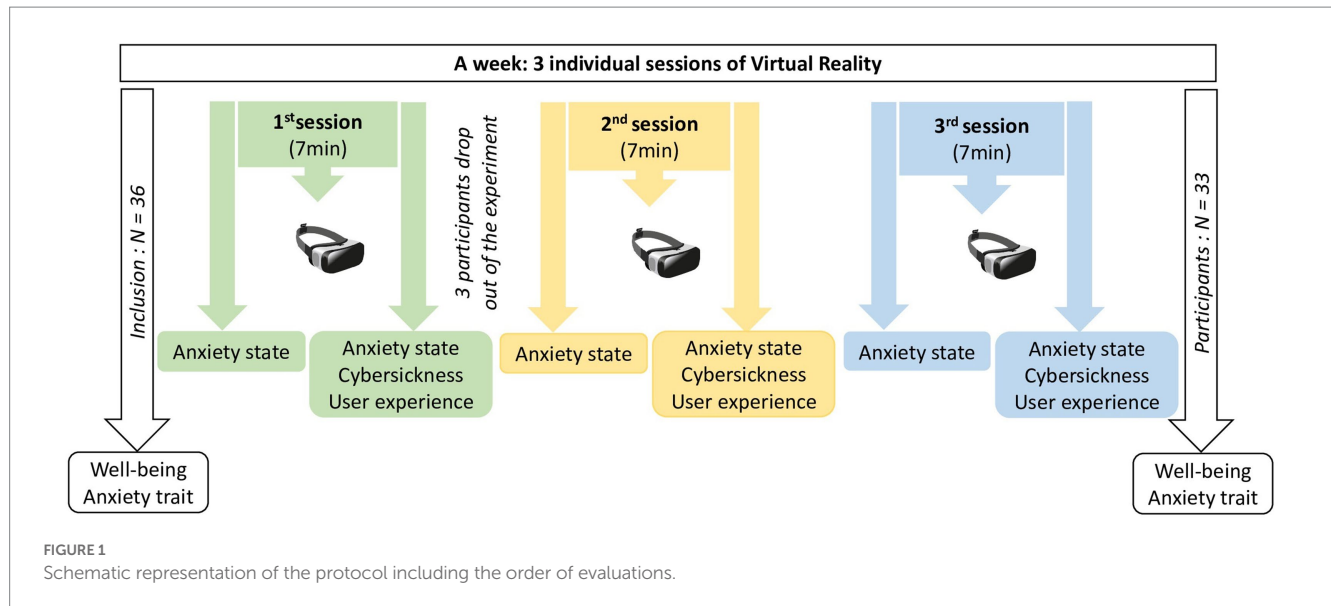VR tolerance was studied using cybersickness (CS) occurrence and anxiety questionnaires.

Cybersickness was measured by the Simulator Sickness Questionnaire (SSQ) (12). This questionnaire has been previously used in several studies to assess cybersickness (27, 28). The French-Canadian translation (29) of this questionnaire, measuring VR's side effects among a sample of French-speaking participants, was used. Each of the 16 SSQ items are rated on a 4-point scale: 0 = none,

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FIGURE 1
Schematic representation of the protocol including the order of evaluations.

FIGURE 2
Prereviews from the Forest Through the Seasons scene (A), Animals of the World scene (B), and The Grand Canyon scene (C).

1 = slight, 2 = moderate, and 3 = severe. They were quoted by the investigator according to answers given by the participants.

Sub-scores of nausea, oculomotor disorder, and disorientation were calculated, and the global score is the weighted average of these sub-scores (12). According to the categorization of Stanney et al. (30), symptoms are considered "negligible" when the global score is <5, "minimal" when between 5 and 10, "significant" when between 10 and 15, and "concerning" when comprised between 15 and 20. Tolerance is considered low when the score is above 20. The population was divided into two groups: SSQ ⩾ 10 at least once vs. < 10 in all three sessions.

Anxiety was assessed by the State–Trait Anxiety Inventory (STAI) (31). The French version (IASTA-Y65+) of this questionnaire, adapted and validated for older adults aged between 65 and 92 (M = 77.5, SD = 7), was used (32). It is composed of two forms (Y-A and Y-B). The two forms of this questionnaire have excellent reliability with a Cronbach's alpha coefficient, respectively = 0.91 and 0.93; $p < 0.05$. Furthermore, a high test–retest stability was found for the two forms of the STAI ($p < 0.001$) (32). Y-A was used to assess the participant's anxiety state (which refers to anxiety in a specific moment) before and after each VR exposure. Y-B was used before the first and after the third session to assess participant anxiety trait (which refers to anxiety

as a trait of personality). Each form scored from 20 to 80; the higher the score, the more anxious the patient.

Well-being was assessed using the Well-Being Index (WHO-5) questionnaire before the first and after the third session (33). The French version published by the (34), validated among older people aged 70.2 years ±8.0, was used (33). This questionnaire has been shown to have good internal consistency and homogeneity among this population (33). Furthermore, recently, the WHO-5 was found to be reliable in 35 countries (including France) and has parameters that do not vary across countries (35). It is composed of five questions (from 0 to 5 points; the higher the score, the better the well-being) (5: All the time, 4: Most of the time, 3: More than, 2: Less than half the time half of the time, 1: From time to time, 0: Never). The total score ranges from 0 to 100.

User experience was assessed after each session using a questionnaire designed specifically for the study. Participants responded to one item assessing perceived usefulness ("Overall, I find this tool interesting"), two assessing perceived enjoyment (e.g., I find the experience relaxing), two assessing perceived ease of use (e.g., "I find the device comfortable"), one assessing intention to use ("I would like to use this device again") on a Likert scale from 1 (strongly disagree) to 6 (strongly agree). These items were

developed based on items commonly used in the Technology Acceptance Model (36) and on other studies specifically investigating technology acceptance by older adults (37–39). The total score ranges from 6 to 36. The higher the score, the greater the experience reported by the participant.

2.2.5. Statistics

Statistical analyses were performed with the JASP 0.16.0 software (which uses R as back-end). Normality was assessed using a Shapiro–Wilk test. The significance of the results was retained for a value of p less than 0.05. Cohen's d was used to characterize the effect size.

The sample size was calculated to ensure a significant difference (5% significance level) between the SSQ scores of CS and a theoretical score of 20 (the score at which CS is severe) (30). For an expected medium effect size of 80% power, the required sample size was 27.

Inference statistics were done by Student t-test for independent samples, ANOVA repeated measures tests were used on SSQ, STAI form Y-A results, and acceptance questionnaire scores. The Holm's *post hoc* test was used on STAI form Y-A scores. A paired t-test was used on STAI form Y-B scores before and after the experiment and on WHO-5 scores.

Described statistics were used to qualify the participant's experience.

3. Results

3.1. Cybersickness

The global SSQ (mean ± standard deviation) was 1.84 ± 3.44. Nausea sub-scores were 0.48 ± 2.72, oculomotor disorder was 2.29 ± 4, and disorientation was 1.96 ± 4.71. Subgroup analysis is provided in Table 1. SSQ scores did not vary significantly over the sessions [$F_{(2, 32)} = 1.22$; $p = $ n.s.] or over the contents [$F_{(2,31)} = 0.005$; $p = $ n.s.]. The mean SSQ score for the two participants who left the experiment because of VR intolerance after the first session was 63.56 ± 10.57. CS evaluation among participants who completed the three sessions showed that HDM VR exposure caused important symptoms, with an SSQ score of $\geqslant 10$ in 8% of cases (8/99 sessions completed). There was no effect of gender on SSQ score ($p = $ n.s.). Six participants (18%) had an SSQ of $\geqslant 10$ at least during one session (mean SSQ 7.89 ± 4.14); of these, five (83%) were women. Among the participants, 61% (20/33) did not report any CS symptoms in any of the sessions and 21% (7/33) had signs of CS during at least one session (mean SSQ 1.95 ± 0.98).

Age, MMSE, anxiety trait, and well-being did not vary significantly between the participants who suffered from cybersickness at least once in the three sessions (SSQ score $\geqslant 10$) and those who had an SSQ

score of <10 (Table 1). There was no effect of repetition [$F_{(2, 32)} = 1.22$; $p = $ n.s] and no effect of VR contents [$F_{(2,31)} = 0.005$; $p = $ n.s] on CS occurrence.

3.2. Anxiety

Significant differences $F_{(32, 160)} = 6.12$; $p < 0.001$, $\eta^2 = 0.16$ in the STAI from Y-A scores were found between measurements. The Holm's *post hoc* test revealed that the score decreased significantly after S1 ($p < 0.05$), S2 ($p < 0.05$), and S3 ($p < 0.05$). It increased significantly before S2 ($p < 0.01$) then before S3 ($p = $ n.s). Anxiety state decreased significantly after each session (Figure 3). No significant difference between the baseline and the final assessment of participant anxiety trait was observed [t $_{(32)} = 0.66$; $p = $ n.s.].

3.3. Well-being

VR sessions' effect on well-being was not significantly different before (mean 56.73 ± 25.48) and after the experiment (mean 60.61 ± 22.61) [t $_{(32)} = -1.13$; $p = $ n.s.]. The experiment had no significant effect on participants' subjective psychological well-being.

3.4. User experience

The global user experience score was (mean 29.92 ± 4.53) for the HMD three-session VR program. The mean scores and standard deviation for each variable of the questionnaire are represented in Table 2.

4. Discussion

This study shows that three immersive VR sessions with HMD tend to be tolerated among nursing home residents, whereas no significant effect on well-being was found.

A total of 61% (20/33) of participants did not report any CS symptoms during the study. This is in agreement with a previous study (40), where no participants (mean age 74.8 years old ±10.4) reported severe discomfort on the SSQ scale when exposed to natural and familial HMD VR scenes. Two participants left the study because of CS intolerance and 18% (6/33) experienced significant CS symptoms ($\geqslant 10$) during at least one session. These symptoms were, however, minimal (mean SSQ < 10) and might have been due to the realistic properties of the VR content. Indeed, two of the proposed scenes are

TABLE 1 Characteristics comparison of participants with SSQ score $\geqslant 10$ during at least one session vs. SSQ score < 10 during all three sessions.

	SSQ < 10 N = 27		SSQ $\geqslant$ 10 N = 6		t	p	Cohen's d
	M	SD	M	SD			
Age	88.89	5.63	91.33	4.63	−0.99	0.33	−0.45
MMSE	25.52	3.04	25	3.46	0.37	0.71	0.17
AT before	32.63	7.51	34.17	5.91	−0.47	0.64	−0.21
WB before	58.37	25.30	49.33	27.33	0.78	0.44	0.35

M, Mean, SD, Standard Deviation, AT, Anxiety Trait, WB, Well-Being.
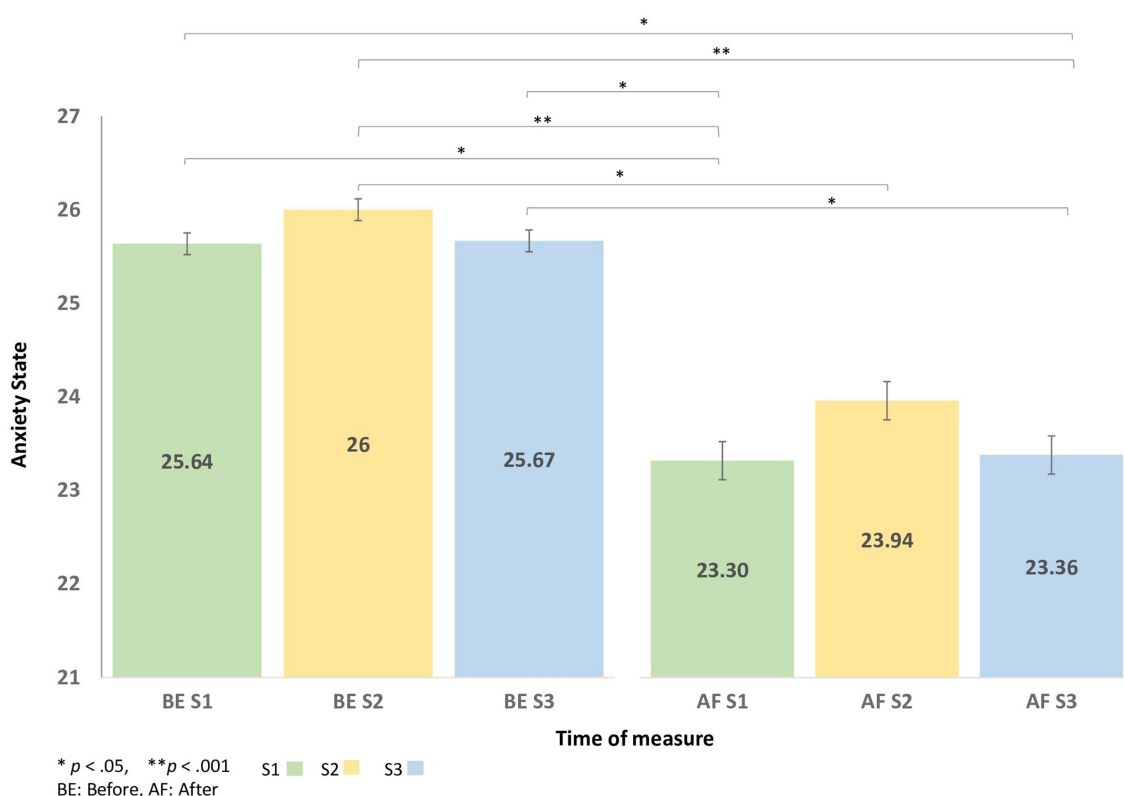
TABLE 2 User's experience results for each variable of the questionnaire.

Variables	Items	M	SD
Perceived usefulness	Overall, I find this tool interesting	4.37	1.29
Perceived enjoyment	I find the experience relaxing I find the experience boring	5.20	0.75
Perceived ease of use	I find the device comfortable I find the experience exhausting	5.44	0.80
Intention to use	I would like to use this device again	4.31	1.38

M, Mean, SD, Standard deviation.

360° realistic live-action films as opposed to the artificially made VR environment experienced in a similar study Huygelier et al. (40). It has already been reported that levels of immersion and realism can influence CS occurrence: the more realistic the VR environment, the higher the CS occurrence (41, 42).

In contrast, some authors have suggested that older adults have a high risk of CS (43, 44) with an SSQ score higher for subjects of 50 years and older than younger subjects (45). The high tolerance in this study may be due to the short time of exposure (7 min), as shorter duration reduces CS (46, 47). Indeed, higher CS rates were found among 118 participants (70 to 90 years old), where sessions lasted 15 min (44). Second, a meta-analysis showed that current-generation VR HMD induces less CS than previous ones (11, 48). Third, VR contents in this study were comprised only of visual interaction with an adaptation to the head movement. This avoids sensorial disparities during the exposure and prevents CS (49).

In order to explain CS susceptibility among the 18% of participants who expressed significant SSQ, we investigated the relationships between participants' characteristics and CS severity. CS occurrence was not implicated by age, MMSE, anxiety trait, and psychological well-being. These results do not in agreement with a meta-analysis, which reports that age and psychological disorder (suffering from significant phobia) are related to VR sickness. Furthermore, it is still not clear whether cognitive abilities are correlated with CS (8).

In our study, anxiety state was considered a non-tolerance indicator. This is in agreement with a review that reported that anxiety before, during, or after VR exposition was associated with VR sickness severity (20). Thus, the decreased anxiety state after each session is in favor of good tolerance of the immersive HMD VR program. This result is also in agreement with a previous study, where an immersive VR reminiscence program with historic live-action scenes and computer-generated images reduced the anxiety state of older adults [mean age (SD): 87.1 (4.2) and mean MMSE (SD): 28.5 (1.2)/30].

This study has several strengths. First, it was conducted among older nursing home residents, a population rarely studied in this field. Second, three different HMD VR contents were studied. Third, the use of the STAI questionnaire provides immediate post-exposure data. Fourth, the questionnaire reflects the user's experience, which is infrequently researched among this population. However, we acknowledge some limitations. First, medical conditions were not recorded. Second, anxiety state was low, which leads us to extrapolate our results to a more anxious population. Third, the proposed VR experience was certainly immersive but not truly interactive, not

allowing a comprehensive assessment of VR tolerance. Finally, to assess user experience, we used a non-validated questionnaire designed to answer specific questions related to VR acceptance. This questionnaire could produce biased results by changing the participants' self-awareness.

5. Conclusion

To conclude, an immersive HMD VR experience was well tolerated among dependent nursing home residents. VR exposure also transiently reduced anxiety without important side effects (except some light CS symptoms) in most participants. Given the good tolerance, it would be interesting to evaluate the effectiveness of a VR program. Further larger studies in this population aiming to identify CS determinants are needed in order to use HMD VR on a standard basis. Finally, it would be useful to take into account the caregiver's opinion in a prospective study with VR exposure.

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 French Ethics Committee East II (2020-A00377-32). The patients/participants provided their written informed consent to participate in this study.

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.

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Technology adoption review for ageing well: analysis of technical solutions

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While several technological solutions are available for older adults to improve their wellbeing and quality of life, little is known about the gaps between the needs, provided solutions, and their adoption from a more pragmatic perspective. This paper reports on reviewing existing technological solutions for older adults, which span the work life, life in the community, and wellbeing at home. We analyzed 50 different solutions to uncover both negative and positive features of these solutions from the perspective of the impact of technology adoption on the quality of life of older adults. Our approach harnesses holistic reasoning to determine the most suitable technologies available today and provides suggestions for improvement toward designing and implementing better solutions.

1. Introduction

Recently, technological solutions have been discovered to cater for the challenges associated with the ageing population (1). Consequently, technology adoption is increasingly important in public health intervention programs to improve the older population's Quality of Life (QoL). Indeed, both mature and evolving technologies have been successfully applied for improving the QoL and health of older adults (2–4).

However, despite the proliferation of technological solutions, and their inherent benefits in improving the QoL of older adults, there seems to be a considerable gap in terms of technology adoption. On one hand, the low level of adoption of new technologies in the ageing population is due to the frequent reluctance and lack of motivation of older adults, and insufficient support available to them (5, 6). On the other hand, the low level of adoption rate is connected to the lack of compliance with policies and strategic frameworks of healthcare and wellbeing. Besides, other complexities associated with multiple factors, such as lack of awareness of potential impact and prevailing bureaucracy, have had a negative impact on technology adoption (1, 7, 8). In addition, there is a lack of quality studies of technology adoption (9–11).

From a more technical perspective, the inability to meet older adults' requirements, including emotional requirements (12), in the design of the technological solutions could endanger human lives (13), which eventually also leads to a low level of adoption. Remarkably, several researchers have pointed out that if the needs of older adults are not adequately captured in the analysis and design process, the system's functionality will not be trusted and reliable (14–16).

The overarching goal of this paper is to analyze the existing technical solutions, as contained in the publications, projects, and patents. In the paper, we answered two important research questions: (i) What are the gaps reported in the literature between the needs, production, and adoption of technology for ageing? and (ii) what are the prevalent challenges associated with technology adoption?

This paper analyzes a selection of recent and most relevant technical solutions from the technology adoption perspective. The technologies have been selected as part of the SHELDON COST action number CA16226 based on a review of existing work by the members of the action. Due to the very large amount of activity in this domain, it does not constitute an exhaustive overview, however it provides a selection of the current most relevant initiatives identified by the members of the COST action. Firstly, our analysis unveils both negative and positive aspects of technology adoption on QoL of older adults. Secondly, we further evaluate the results of the analysis by means of statistical measures. Thirdly, the main contribution of this paper are the recommendations and policy implications we can deduce from the analysis. Clearly, the focus is to understand the gaps between the needs, production, and adoption of solutions targeted at older adults.

The structure of the paper is as follows. Section 2 describes the background and motivation, while Section 3 discusses the theoretical frameworks used as guidelines for analyzing the technical solutions. This is followed by the description of our methodological approach in Section 4. Section 5 contains the analysis of the results and Section 6 presents the discussions. Section 7 presents the strengths and limitations of the study. Finally, Section 8 concludes the paper with some recommendations and suggestions.

2. Background and motivation

There is a rapid growth in the number of older adults across all continents. According to Ollevier et al., (17), the expected growth of the number of older adults would be well above 60% in another 15 years. According to the reports on the ageing of the world population by the United Nations (18, 19), by 2030, ∼1 billion older adults will make up 12% of the whole world population (20). In this context, a number of challenging problems will have to be solved because of the ageing population (21).

Technology has a great potential in providing the support needed for enhancing the healthy lifestyle of older adults (22–24). The development and adoption of this kind of technology is a crucial factor for older adults to compensate for psychological, social, and biological changes occurring in them over time (2), such as the loss of adaptability and functional impairments (25).

Interestingly, the technologies available for older adults have engendered significant changes in recent times. Notably, we have witnessed the use of assistive technologies (22, 26, 27), health monitoring systems, the Internet of Things (IoT) solutions (e.g., wearable devices) (23, 28, 29), smart sensors (3, 30), medication reminders (31), telemedicine applications (32), and social networking applications (9) for enhancing the QoL of older adults.

It is noteworthy that the Ambient Assisted Living (AAL) and Enhanced Living Environments (ELE) technologies comprise significant contributions from researchers in ICT and psychology (33–35). Remarkably, the idea of an ELE refers to the ICT-related part of AAL, which means that ELEs incorporate all ICT advancements to assist AAL (36). The psychological aspects of AAL deal with human behaviors, affects, emotions, and desires. On the other hand, ELE focuses on designing and implementing suitable technologies based on psychological theories of automated systems (37). Additionally, ELE incorporates the most recent innovative achievements in IoT to create better ICT solutions for improving the health and wellbeing of older adults (36).

Encouraging older adults to adopt the technologies aimed to improve their health and wellbeing has received a lot of attention in the research literature (38–40). It is worth of mentioning that technology is repeatedly mentioned to support ageing in place (41, 42). For example, in the FeelGood project (43), a framework was created for supporting and promoting self-management of wellbeing concerns through technology adoption. Also, technological innovations in the Netherlands have enabled to increase the number of dwelling places suitable for older adults (44). However, while most organizations are optimistic about the impact of technology on improving healthy lifestyles of older adults, they tend to focus on its cost rather than its benefits (45–49).

Although technological innovation promises to continuously enhance the health and wellbeing of older adults, the seamless adoption of such technologies from both the human and technical perspectives can be a limiting factor for a sustainable breakthrough or progress (50, 51). Therefore, there is a need to identify and investigate existing solutions and analyze them for their strengths and weaknesses from the technology adoption perspective.

3. Theoretical framework

Although the terms "technology acceptance" and "technology adoption" are sometimes used interchangeably, they are not synonymous. On the one hand, "technology acceptance" is a perception of technology that is impacted by various factors. These factors include frequency of use, usage experience, ease of use, usefulness, attitude, usage knowledge and enjoyment (52). On the other hand, "technology adoption" is a process that starts with knowledge of the technology and ends with acceptance and full utilization of the technology. Accepting technology without adopting it is therefore conceivable, but full adoption is impossible

without acceptance (53). In the literature, several technology adoption theories exist. However, this paper examines technology adoption among older adults using two theoretical frameworks. The first is the Technology Acceptance Model (TAM) by Davis (54), and the second is Everett Rogers' Diffusion of Innovation (DOI) theory (55).

3.1. TAM

TAM is a widely used adoption theory (56–58) that focuses on how people make technology adoption decisions (59, 60). It was derived from the Theory of Reasoned Action (TRA), which is a socio-psychological theory that determines how people will act given their preceding attitudes and Behavioral Intentions (BI) (61, 62). BI is "the degree to which an individual has formulated conscious plans to perform or not to perform some specified behavior in the future (54)." It is predicted by both attitude and perceived usefulness (53).

Further, TAM was formulated to predict and explain technology acceptance and use. In this regard, Davis et al. (59) proposed two significant factors as critical determinants of technology adoption: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). According to Davis (54), Perceived Usefulness is "the degree to which a person believes that using a particular system would enhance his or her job performance," while Perceived Ease Of Use is "the degree to which a person believes that using a particular system would be free of effort." Thus, PU and PEOU are technological variables that emphasize people's attitudes, perceptions, and interactions with technology (63).

Over the years, this area has further developed and TAM has been extended. One such extension is TAM 2, which replaced the attitudinal component of TAM with a social element termed as Subjective Norm (SN) (64). The theory behind TAM 2 claims that cognitive instrumental processes explain perceived utility and usage intentions (e.g., job relevance, output quality, outcome demonstrability, and perceived simplicity of use) as well as social influence processes (subjective norm, voluntariness, and image) (64). Another extension of standard TAM is the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT differs from TAM in that it includes social and environmental variables and technological factors as determinants of behavioral intention (65).

Notably, many studies have shown that a strong intention of technology usage results in a high probability of actual usage (66). This implies that a person intending to use technology will most likely use it. As a foundational technology adoption theory, TAM is useful in examining the potential adoption of a given technology among older adults. Yap et al. (67) divided the antecedents of technology usage among older adults into the following seven categories: technological, psychological, social, behavioral, cost-related, personal, and environmental. Antecedent, in this case, indicates pre-existing factors that determine or influence technology adoption by older adults. The source (67) reviewed twenty-six (26) research articles on technology adoption, most of them focusing on TAM and its variables PU and PEOU.

3.2. DOI

Everett Rogers did put forward the Diffusion of Innovation (DOI) theory for examining technology adoption and determining how technological innovations diffuse within communities (55, 68). On one hand, diffusion is the process by which an innovation spreads over time and through specific channels among the people within a social system (69, 70). On the other hand, innovation is "an idea, practice, or object perceived as new by an individual or other unit of adoption (69, 70)."

Rogers et al. (69) distinguished between the processes of innovation decisions by individuals and groups. To reduce innovation uncertainty, decision-making units must follow a specific procedure before deciding whether to accept or reject an innovation (69, 70). As observed by Zhang (71), communication channels, innovation attributes, adopter characteristics, time, and the social system are the five essential variables that determine the success of innovation. Regarding technology adoption, the DOI theory recognizes the following five stages: knowledge or awareness, persuasion, decision, implementation, and confirmation.

3.3. Inferences observed in TAM and DOI

We observed that TAM is limited as a theory because of its position that technology adoption by older adults solely depends on the features of particular technologies to be adopted. In reality, older adults also think about how a technology enables their lifestyle in ways they value (67). Therefore, TAM does not sufficiently explain the adoption of technologies by older adults. To compensate for that, we have also incorporated the Diffusion of Innovation (DOI) theory to complement TAM for a more holistic analysis. Overall, the growing impact of technology on older adults cannot be underestimated. It has been observed that technology usage improves social, mental, and emotional wellbeing of older adults, while also decreasing their feeling of loneliness (72). Therefore, we used both TAM and DOI as the significant drivers of technology adoption among older adults as has also been reported in Heo et al., Mahoney, Hastall et al., and Cahill et al. (73–76).

Differently, we blended the TAM and DOI theories to provide adequate insight into the analysis of technology adoption among older adults for improving the QoL and facilitating healthy lifestyle. In particular, we used from the TAM model as technological issues the improved wellbeing, ease of use, willingness to accept technology, and understandability. At the same time, we used from the DOI model as technological issues the technological awareness, willingness to accept technology, effectiveness, and understandability. Based on these technological issues identified from the two theories, we formulated hypotheses for statistical analysis.

4. Methods

We designed our study using a mixed method consisting of the methods of qualitative explorative approach (77), and quantitative research (78), which have been synthesized as is described by

FIGURE 1
Systematic process for technology adoption review: adapted from Kitchenham (80).
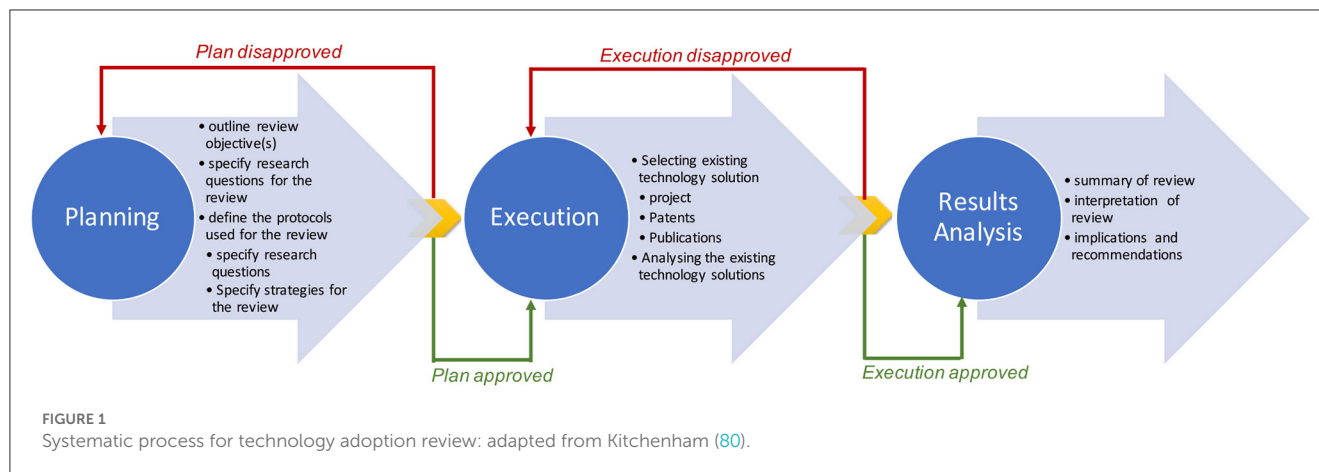
Dixon-Woods et al. (79). The qualitative explorative approach focuses on a critical and extensive review of the existing solutions, while the quantitative research involves using statistical measures to further improve the analysis.

We followed the systematic process described in Figure 1 to analyze the shreds of evidence reported about the existing solutions by answering the research questions mentioned in Section 1. Figure 1 is a modified version of the three-step process of systematic review: *planning, execution (i.e., carrying out the research), and result analysis* (80).

In the *"planning"* phase, we outlined our review objective(s), specified the questions for the review, and defined the protocols used for the review. In the *"execution"* phase, we selected and analyzed the existing technology solutions. Finally, we summarized the review during the *"result analysis"* phase.

Overall, we analyzed 50 existing solutions[1]—projects, patents, and publications—to uncover both negative and positive examples of technology adoption and their impact on QoL of older adults. The selected 50 solutions used for the technology adoption review are part of the SHELDON COST action number CA16226 by the SHELDON Working Group 4.4, which aims to review the current state of the art in technologies for smart living environments. The technologies presented are chosen by the action members based on their relevance and impact in this domain, especially for improving the QoL of older adults. The authors and other COST action members selected the most relevant technologies, projects, patents, and papers for this paper's analysis. We used keyword-based queries in the main online search tools that give a representative sample of the most promising initiatives from the COST action, which include projects, patents, or technological systems.

All the authors were involved in reviewing the 50 existing solutions. Based on the guidelines provided by Kitchenham (80), we adopted the random selection technique to determine the reviewers of particular existing solutions. Consequently, each author decided on the document—project, patent, or technological system—to be reviewed from the list of the documents provided by the SHELDON Working Group 4.4 on technology adoption. The last author coordinated the review process. The objective of the review was 2-fold. The first goal was to understand the gap between the

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1 https://bit.ly/3RmsS3W.

need, solutions, and technology adoption. The second goal was to understand the adoption challenges and the features of the solutions reported in various documents. Based on the resulting reviews, we analyzed from the technology adoption perspective the technical solutions provided by different projects.

4.1. Procedure for qualitative analysis of technology adoption

We summarize the reviews provided by the authors by identifying the strengths and weaknesses of each existing solution that was analyzed. For that purpose, three analysis questions were asked for each solution as guides for understanding the gap between the need, solution, and technology adoption. These questions also served as the roadmap for understanding the adoption challenges faced by these solutions that have been reported in various documents. The analysis questions were as follows:

1. AQ1: Has the technology been tried out?
2. AQ2: Has the technology been tried out in a case study involving real end users?
3. AQ3: How well did the end users adopt the solution?

Additionally, we used ten (10) criteria based on the above analysis questions to elaborate our analysis. Table 1 describes the criteria that were applied to the analysis.

4.2. Procedure for quantitative assessment of analysis

We employed a quantitative assessment method to establish the suitability of a particular technology for ageing well. Regarding that, we formulated the null hypothesis H_0 and alternative hypothesis H_1, which were later subjected to a statistical test to verify their validity. In particular, we used the T-test and correlation analysis. We tested H_0 with ten (10) randomly selected people within the age range between 60 and 75 by asking them a number of questions based on the TAM and DOI theoretical frameworks.

TABLE 1 Criteria for analyzing technology adoption.

SN	Criteria used for analysis	Key	Aspects
1.	Technology has been used or tried out	+	Positive
2.	Technology has not been used or tried out	−	Negative
3.	End users have started using the technology	+∗	Positive
4.	End users have not started using the technology	−∗	Negative
5.	Technology has been tried out in a case study by real users	++	Positive
6.	Technology has not been tried out in a case study by real users	–	Negative
7.	Prototype assessment/evaluation with real end users	±	Positive
8.	Prototype assessment/evaluation without real end users - only simulation	≠	Negative
9.	The end users have adopted the technology well	1	Positive
10.	The end users have not adopted the technology well	0	Negative
11.	Information about the items 1–10 is not available	NA	NA

TABLE 2 The identified technology adoption issues.

SN	Identified issue and the corresponding theory	Response
1.	Technological awareness—DOI	Either: SA, PA, N, PD, SD
2.	Support—DOI and TAM	Either: SA, PA, N, PD, SD
3.	Improve wellbeing—TAM	Either: SA, PA, N, PD, SD
4.	Safety and security—DOI	Either: SA, PA, N, PD, SD
5.	Ease of use—TAM	Either: SA, PA, N, PD, SD
6.	Privacy and confidentiality—DOI	Either: SA, PA, N, PD, SD
7.	Affordability—DOI	Either: SA, PA, N, PD, SD
8.	Confidence and trust—DOI and TAM	Either: SA, PA, N, PD, SD
9.	Willingness to accept technology—DOI and TAM	Either: SA, PA, N, PD, SD
10.	Satisfaction—DOI and TAM	Either: SA, PA, N, PD, SD
11.	Effectiveness—DOI	Either: SA, PA, N, PD, SD
12.	Understandability—DOI and TAM	Either: SA, PA, N, PD, SD

SA, Strongly agree; PA, Partially agree; N, Neutral; PD, Partially disagree; SD, Strongly disagree.

The structure of the questions that were used to source data from the 10 randomly selected persons is shown in Table 2. The 10 randomly chosen persons are from Tartu, Estonia. Following their verbal consent, they were interviewed informally. As Table 2 reflects, the given technology adoption issues were selected because they have been regarded as the most prevalent ones in the literature (73–76). The questions were designed to capture the individual's opinions on the possible use of a particular technology for improving the QoL of older adults. This is important for determining the levels of technology acceptance of end users for using these technologies.

As Table 2 shows, technological awareness is a factor aligned with DOI. It is one of the innovation model's stages of technology adoption. For this study, technological awareness refers to the knowledge of older adults about the existing technology.

Additionally, support focuses on improving wellbeing, safety, security, ease of use, privacy and confidentiality, affordability, confidence, trust, willingness to accept technology, satisfaction, effectiveness, and understandability. All these are a mixture of TAM and DOI.

5. Results

This section presents the results based on the theoretical framework explained in Section 3 and methodology presented in Section 4.

5.1. Analysis of the existing solutions

According to the objectives of our analysis, six of the technological issues identified in Table 2 were analyzed to see if a relationship exists between technology adoption and technological issues and if one technological issue depends on another.

Based on the criteria described in Table 1, we critically analyzed the existing solutions. Table 3 presents details of the analysis showing the positive and negative aspects of the existing solutions.

5.2. Statistical evidence of analysis

From our initial discussion with selected respondents, we found out that they have a significant ability to use technology, especially operating their mobile devices and other digital devices they currently use, to adopt healthier lifestyles. The responses that we received are presented in Table 4.

As Table 4 reflects, the response by each participant was captured for each issue that we identified as the major driver that positively affects technology adoption by older adults, based on the TAM and DOI theoretical frameworks.

We categorized the responses as "Yes," "No," and "Neutral." "Yes" means that the respondent either strongly agreed or

TABLE 3 Analysis of the existing solutions.

SN	Name of solution	Positive aspects	Negative aspects
1	The HOLOBALANCE project	±	-, -*, −, 0
2	The My-AHA project	NA	NA
3	The HOPE project	+, +*, ++, ±	0
4	The Agnes project	+, ++, ±	-*, 0
5	The Pharaon project	+	-*, −, ≠, 0
6	The SMART-BEAR project	+, ±	-*, −, 0
7	The GATEKEEPER project	+	-*, −, ≠, 0
8	The SHAPES project	±	-, -*, −, 0
9	The FeelGood project	+	-* − ≠0
10	The MPOWER project	NA	NA
11	The OpenAAL project	+, ±	-*, −, 0
12	The PERSONA project	+	-*, −, ≠, 0
13	The RAFAALS project	+	-*, −, ≠, 0
14	Patent: An auxiliary system and a method for monitoring the health of the aged at home based on the IoT	+	-*, −, ≠, 0
15	Patent: Smart home service robot system based on diet and health management	+	-*, −, ≠, 0
16	Patent: Intelligent nursing home, intelligent management system	+	-*, −, ≠, 0
17	Patent: Cloud-computing-based method and apparatus for extraction and analysis of daily life and diet information of older adults living at home	+	-*, −, ≠, 0
18	Patent: Intelligent healthy diet recommendation system combined with mobile terminal	+	-*, −, ≠, 0
19	Patent: Monitoring system and sensor shoes for socials safety nets of older adults	+	-*, −, ≠, 0
20	Patent: Sports for older adults risk evaluation method	+	-*, −, ≠, 0
21	Patent: Intelligent exercise detection system based on multiple sensors and production device	+	-*, −, ≠, 0
22	Patent: Method for providing AI type care service for shopping healthcare company and game	+	-*, −, ≠, 0
23	Patent: IoT nighttime tracing light for older adults	+	-*, −, ≠, 0
24	Patent: Intelligent system for chaperoning of senior citizens	+	-*, −, ≠, 0
25	Patent: Mobile smart monitoring device for the apartments of older adults	+	-*, −, ≠, 0
26	Patent: Older adult care medical management system	+	-*, −, ≠, 0
27	Patent: Communication support robot system	+	-*, −, ≠, 0
28	The MobileAge project	+	-*, −, ≠, 0
29	The Homes4Life Certification project	+	-*, −, ≠, 0
30	The SmartHabits project: An Intelligent Privacy-Aware Home Care Assistance System	+	-*, −, ≠, 0
31	Active and Healthy Ageing at Work–A Qualitative Study with Employees 55–63 Years and Their Managers	NA	NA
32	I-CARE-SMART: co-creation in care for older adults	+	-*, −, ≠, 0
33	The SustAGE project	+	-*, −, ≠, 0
34	Intracom Medical ICT Solutions Portfolio	+	-*, −, ≠, 0
35	Joint deep learning and Internet of medical things based framework for older patients	+	-*, −, ≠, 0
36	Paper: Architecture and Implementation of an Internet Platform for Activating Older People: Case Study	+	-*, −, ≠, 0
37	Product: AIBO robot	+, +*, ++, ±	0
38	Product: NAO robot	+	-*, −, ≠, 0
39	Product: PARO robot	+, +*, ++, ±	0
40	Paper: ALL-VU system	+, ±	-*, −, 0

(Continued)

TABLE 3 (Continued)

SN	Name of solution	Positive aspects	Negative aspects
41	Paper: Senior App Suit	+, ++, ±	-*, 0
42	Paper: Virtual reality	+, ++, ±	-*, 0
43	Paper: Inferring loneliness levels in older adults from smartphones	+, ±	-*, −, 0
44	Paper: A Smart-Home System to Unobtrusively and Continuously Assess loneliness in Older Adults	+, ++, ±	-*, 0
45	The FACTAGE project—Fairer Active Ageing for Europe	NA	NA
46	Service: SeniAngel	+, +*, ++, ±, 1	NA
47	Patent: Old man dementia prevention and safety management system	+	-*, −, ≠, 0
48	Patent: Older adult health condition monitoring underwear based on somatosensory technology	+	-*, −, ≠, 0
49	Patent: Older people living alone monitoring device using the IoT	+	-*, −, ≠, 0
50	Patent: Device and method for acting as a friend in smart ageing service	+	-*, −, ≠, 0

TABLE 4 Responses from randomly selected people.

Issue	P1%	P2%	P3%	P4%	P5%	P6%	P7%	P8%	P9%	P10%	AVE($\bar{X}$)
Technological awareness	75	100	50	75	0	100	25	50	100	75	65
Support	75	75	25	100	50	75	25	50	50	75	60
Improve wellbeing	100	100	100	100	75	100	75	75	100	100	92.50
Safety and security	75	100	75	50	50	75	50	50	75	75	67.50
Ease of use	75	100	50	75	50	100	25	50	100	100	72.50
Privacy and confidentiality	75	75	50	75	50	100	25	50	75	75	65
Affordability	50	50	25	50	75	75	50	50	50	75	55
Confidence and trust	100	100	50	75	75	100	50	50	100	75	77.50
Willingness to accept technology	100	100	75	100	100	100	75	50	100	75	87.50
Satisfaction	100	100	75	75	75	100	75	50	100	75	82.5
Effectiveness	75	100	75	100	75	75	50	50	100	75	77.50
Understandability	75	100	75	75	75	100	75	50	100	100	82.50
Average ($\bar{X}$)	81.25	91.67	60.42	79.17	62.50	91.67	50	52.08	87.50	81.25	

SA = 100; PA = 75; N = 50; PD = 25; SD = 0; P Participant; $\bar{X}$ Average.

partially agreed that a given issue should be among the technology adoption issues to be considered. If the participant strongly agreed that a given issue should be included, 100% was assigned. If the participant partially agreed, 75% was assigned. If the participant's response was neutral and they neither agreed nor disagreed, 50% was assigned. "No" means that the respondent either partially disagreed or strongly disagreed on the matter. If the participant partially disagreed, 25% was assigned and if the participant strongly disagreed, 0% was assigned. The percentages reflecting the responses by the participants to the technology adoption issues are shown in Table 4.

Additionally, we identified from the responses by the participants shown in Table 4 the degrees of their agreement about the importance of different technology adoption issues. The degrees of agreement are shown in Figure 2. According to the results, the technology adoption issue *improve wellbeing* has the highest relevance.

5.2.1. *T*-test analysis

We first conducted a statistical test to check the validity of the following null hypotheses (H_0) and alternative hypotheses (H_1). Table 4 shows that the data is normal and meets the assumption for basic *t*-test analysis. The hypotheses were as follows:

I. Hypothesis on *improve wellbeing*

- H_0: *Adopting technologies by older adults cannot improve their wellbeing.*
- H_1: *Adopting technologies by older adults can improve their wellbeing.*

The input data: improve_wellbeing, $t = 24.222$, df = 9, *p*-value = 1.667e-09, 95% confidence interval: 83.86124–101.13876, sample estimates: mean of x = 92.5.

The average percentage of each response was calculated and the H0 test was applied to it. Adopting a sample *t*-test technique at ±

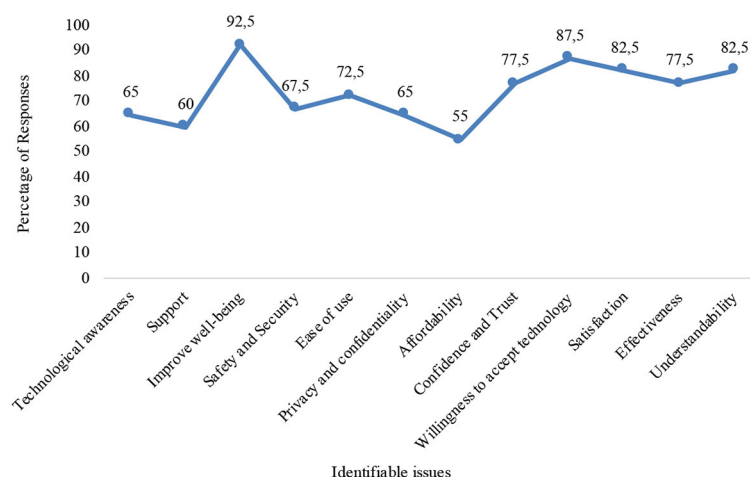**FIGURE 2**
Technology adoption issues.

= 0.05, the *t*- value of 24.222 was obtained. Using the standard *t*-table for 9 degrees of freedom, we reject the null hypothesis if the calculated value of *t* is greater than the critical value of *t*, which is 2.262. Since the obtained *t*-value of 24.222 is greater than the critical value of *t*, we reject the null hypothesis and accept the alternative hypothesis, which states that adopting technologies by older adults can improve their wellbeing.

II. Hypothesis on *technological awareness*

- H_0: *Technological awareness is not statistically significant for technology adoption by older adults.*
- H_1: *Technological awareness is statistically significant for technology adoption by older adults.*

The data input: technological_awareness, t = 6.0908, df = 9, *p*-value = 0.000181; 95% confidence interval: 40.85854–89.14146; Sample estimates: mean of x = 65.

The statistical test presented above shows that at the confidence interval of 95%, degree of freedom of 9, and alpha value of 0.05, the *t*-value is 6.0908, which is greater than the critical value of *t*, which is 2.262. Therefore, we reject the null hypothesis and accept the alternative hypothesis, which states that technological awareness is statistically significant for technology adoption by older adults.

III. Hypothesis on *willingness to accept technologies*

- H_0: *Willingness to accept technologies is not statistically significant for technology adoption by older adults.*
- H_1: *Willingness to accept technologies is statistically significant for technology adoption by older adults.*

The input data: willingness_to_accept_technology t = 15.652, df = 9, *p*-value = 7.79e-08; 95% confidence interval: 74.85416–100.14584; sample estimates: mean of x = 87.5.

The statistical test presented above shows that at the confidence interval of 95%, degree of freedom of 9, and alpha value of 0.05, the *t*-value is 15.652, which is greater than the critical value of *t*, which is 2.262. Therefore, we reject the null hypothesis and accept the alternative hypothesis, which states that willingness to accept technologies is statistically significant for technology adoption by older adults.

IV. Hypothesis on *understandability vs technology adoption*

- H_0: *Understandability is not statistically significant for technology adoption by older adults.*
- H_1: *Understandability is statistically significant for technology adoption by older adults.*

The input data: understandability; t = 15.461, df = 9, *p*-value = 8.67e-08; 95% confidence interval: 70.42927–94.57073; sample estimates: mean of x = 82.5.

Accordingly, at the confidence interval of 95%, alpha value of 0.05, and 9 degrees of freedom, the *t*-value is 15.652, which is greater than the critical value of *t*, which is 2.262. Therefore, we reject the null hypothesis and accept the alternative hypothesis, which states that understandability is statistically significant for technology adoption by older adults.

V. Hypothesis on *ease of use*

- H_0: *Ease of use is not statistically significant for technology adoption by older adults.*
- H_1: *Ease of use is statistically significant for technology adoption by older adults.*

The input data: ease_of_use; t = 8.3331, df = 9, *p*-value = 1.596e-05; 95% confidence interval: 52.81865–92.18135; sample estimates: mean of x = 72.5.

Accordingly, at the confidence interval of 95%, alpha value of 0.05, and 9 degrees of freedom, the t-value is 8.3331, which is greater than the critical value of t, which is 2.262. Therefore, we reject the null hypothesis and accept the alternative hypothesis stating that ease of use is statistically significant for technology adoption by older adults.

VI. Hypothesis on *support and technology adoption*

- H_0: *Support is not statistically significant for technology adoption by older adults.*
- H_1: *Support is statistically significant for technology adoption by older adults.*

The input data: support; t = 7.8558, df = 9, p-value = 2.559e-05; 95% confidence interval: 42.72249–77.27751; sample estimates: mean of x = 60.

Accordingly, at the confidence interval of 95%, alpha value of 0.05, and 9 degrees of freedom, the t-value is 7.8558, which is greater than the critical value of t, which is 2.262. Therefore, we reject the null hypothesis and accept the alternative hypothesis stating that support is statistically significant for technology adoption by older adults.

5.2.2. Correlation analysis

The main objective of this study is to understand the gap between the needs, provided solutions, and their adoption. We also identified several technology adoption issues and analysed their relevance. In this section, we analyze the correlation between several identified technology adoption issues by postulating a number of statistical hypotheses.

I. Hypothesis on *technological awareness and willingness to accept technologies*

- H_0: *There is no statistical relationship between technological awareness and willingness to accept technologies.*
- H_1: *There is a statistical relationship between technological awareness and willingness to accept technologies.*

Figure 3 presents the analysis results of the correlation between technological awareness and willingness to accept technologies. The input data: technological_awareness and willingness_to_accept_technology; t = 1.0541, df = 8, p-value = 0.3226; 95% confidence interval: –0.3594439–0.8024112; sample estimates: correlation = 0.3492151.

The correlation between technological awareness and willingness to adopt technologies is 0.3492151, indicating a weak positive relationship between the variables. The p-value of 0.3226 indicates that the correlation coefficient is significant. However, there is a weak relationship between technological awareness and willingness to accept technologies, which may result from sentiments about the device or the inability to operate the device. The alternative hypothesis is accepted.

II. Hypothesis on *support and improve wellbeing*

- H_0: *There is no statistical relationship between support and improved wellbeing.*
- H_1: *A statistical relationship exists between support and improved wellbeing.*

Figure 4 presents the analysis results of the correlation between support and improved wellbeing. The data input: support and improve_wellbeing; t = 1.7393, df = 8, p-value = 0.1202; 95% confidence interval: –0.1578894–0.8673726; sample estimates: correlation = 0.5238095.

The correlation between support and improve wellbeing is 0.5238095, which shows a moderate positive relationship between the variables, and the p-value of 0.1202 indicates that the relationship between support and improve wellbeing is statistically significant. Therefore, we can conclude that if the support obtained from technological devices increases, the wellbeing of older adults will improve.

III. Hypothesis on *understandability and ease of use*

- H_0: *There is no relationship between understandability and ease of use.*
- H_1: *A relationship exist between understandability and ease of use.*

Figure 5 presents the analysis results of the correlation between understandability and ease of use. The data input: understandability and ease_of_use; t = 3.6793, df = 8, p-value = 0.006225; 95% confidence interval: 0.3258361–0.9488141; sample estimates: correlation = 0.7928129.

The correlation between understandability and ease of use is 0.3492151, indicating a strong positive relationship between the variables. The p-value of 0.006225 also suggests that the correlation coefficient is significant. Therefore, a statistical relationship exists between understandability and ease of use.

6. Discussion

This section discusses the findings from selected existing solutions based on our results. Also, we discussed the implications of the statistical evidences of our analysis.

6.1. Some findings from selected existing solutions

This subsection further discusses some findings from solutions selected from Table 3.

Solution 1: The older adults found the system worked out in the HOLOBALANCE project encouraging and stimulating. The virtual coach was perceived as an alive, calm, intelligent, and friendly human. However, the usability of the entire virtual reality (VR) system showed a significant negative correlation with the participants' age. In the HOLOBALANCE project, mock-up interfaces were evaluated in semi-structured focus groups.
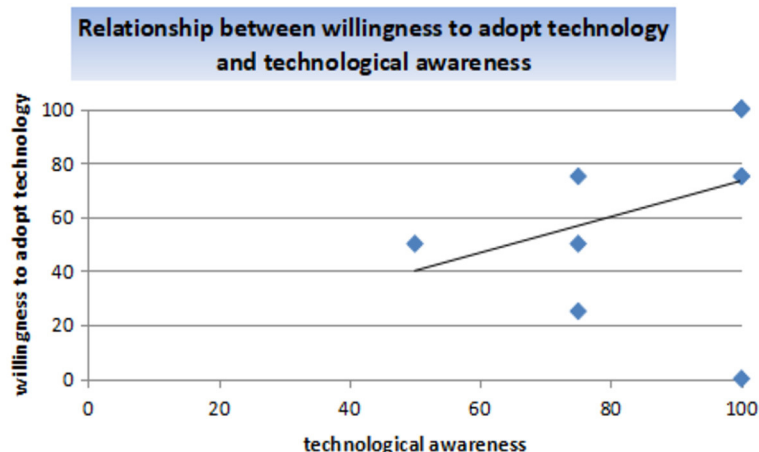
FIGURE 3
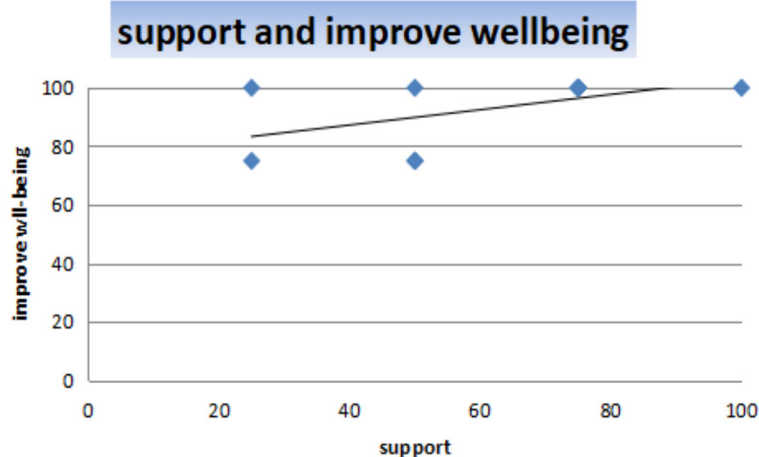Correlation between technological awareness and willingness to accept technologies.

FIGURE 4
Correlation between support and improve wellbeing.

Interviews were performed across three European countries. Also, a set of proof of concept validation studies were deployed, which aimed at assessing the accuracy of the different components of the sub-modules of the motion capture and assessment. The technology worked out in the project has potential for exploitation and commercialization as a service based on the IoT framework and on the accompanying business model of the continuous care and coaching platform. The validation results provide evidence that the proposed system can accurately support and assess physiotherapy exercises to care for balance disorders. This improves a patient's commitment to rehabilitation programs while enhancing the quality of the performed exercises. At the same time, we also indetified several negative aspects of the project in terms of technology adoption.

Solution 2: The My-AHA project is a typical ICT infrastructure with data analytics that is applied to the detection of frailty. The focus is not on technical innovation but on the concept of frailty

and how to detect and take care of it. For this project, none of the criteria included by Table 1 were applicable.

Solution 3: The platform worked out in the HOPE project relies on a universal control box to interconnect a variety of devices. For this platform, the technology adoption involves buying the box and configuring the devices for it.

Solution 4: The Agnes project is an integration of ICT and social networking services that aids the detection of user states and activities and meeting the needs of older adults. The solution worked out in the Agnes project has the potential of prolonging for older adults the time spent at home, preserving health and promoting a healthy lifestyle, preventing social isolation, and providing support for (in)formal carers.

Solution 9: The FeelGood project provides a roadmap for an ecosystem for Finnish companies to excel in the international competition for services Personal Health Records (PHR). The PHRs form a part of the foundation of the healthcare system
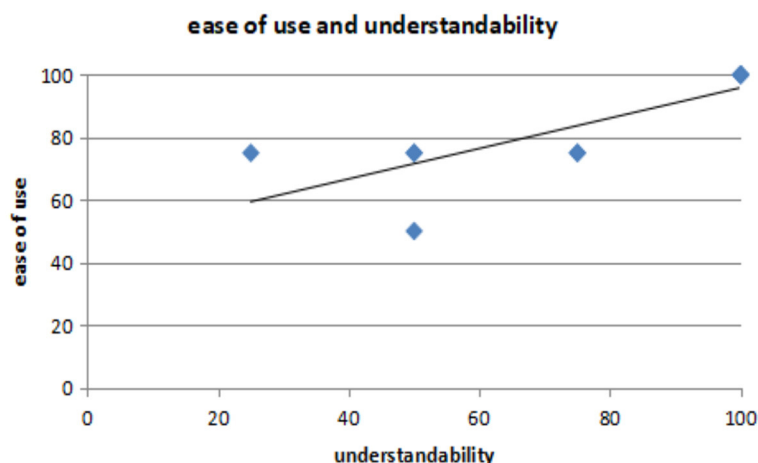
in Finland. The motivation of the project was to encourage the continuous utilization of e-services in the healthcare sector. The roadmap serves as a catalyst to transform the current illness-centered healthcare systems into a service landscape that allows patients and citizens to work in a partnership with healthcare providers to manage health issues. Several stakeholders participated in formulating a strategic roadmap for improving the PHR-based services in Finland. The roadmap focuses on providing an enabling environment for supporting and promoting healthcare concerns for the citizens through technology adoption. Although the formulated roadmap seems promising in terms of the approach and strategy employed, it is not certain whether the roadmap will be accepted by all the healthcare professionals and government.

Solution 10: The MPOWER project involves the cooperation platform, which is a technical integration platform of various services. It is a multisensor and multidevice environment that can provide support for the ageing population. However, technical solutions included by the platform are not directly applicable to senior users and their environments.

Solution 17: This solution systematically extracts and analyzes health and dietary information about older adults. It utilizes the information received from individual devices to form comprehensive and integrated information that can be used by different stakeholders, such as informal caregivers, to gain an insight into the QoL of older adults living at home.

Solution 18: This solution makes dietary recommendations and performs dietary monitoring of older adults. The recommendations are made based on the knowledge about the particular older adult rather than by following generic rules.

Solution 28: The MobileAge project produced the "Best Practice Guide for Co-creation of Open Public Services," and is meant for co-design experts rather than end-users. The guide was evaluated in six co-creation case studies in Greece, Germany, the UK, and Spain but not in real-life cases. Unfortunately, the guide contains too many different methods without any clear directions as to in which order and situations one or another method should be applied. Furthermore, we could not find

evidence of the OSCPSEP platform having been used in real-life case studies.

Solution 30: The SmartHabits project resulted in a system that was validated in a real environment, where a pilot application was set up in the city of Zagreb in cooperation with the foundation taking care of the older adults living alone. The validation confirmed that the proposed system has a potential to improve the quality of care by utilizing simple smart home sensors that can provide essential and continuous information about the occupant's status and environment. This was demonstrated in a scenario focused on prolonging the independence of the older adults living alone while offering peace of mind to their informal and formal caregivers. The system has great potential for adoption because of being non-invasive, self-adaptable to user behavior, zero-touch, and easy to manage. The most significant challenge of the adoption lies in the trust in technology.

Solution 32: The I-CARE-SMART project developed the following three methodological materials: ToolBox for Senior Engagement, ToolBox for Business Engagement, and Handbook on Co-Creation and Open Innovation Methods for Smart Care to Older Adults. These methods have not yet been validated in any real-life case studies.

Solution 33: The validation results of the pilots of the The SustAGE project have not been yet published. There is an extensive exploitation strategy, but its feasibility is hard to assess without knowing the validation results.

Solution 34: In the Intracom Medical ICT Solutions Portfolio project, a cloud-based integrated solution offering the PACS/RIS (Picture Archiving and Communication System / Radiology Information System) functionalities was provided as a service. Older adults are mentioned as potential customers, but there is no information about the actual usage or adoption.

Solution 35: In the "Joint deep learning and Internet of medical things based framework for elderly patients" project, the decision agent provides feedback to an inference engine of the target language analysis agent and the dialogue situation determination agent to allow for subjective interpretation of a given situation

experienced by the older adult. However, devices that work and that do not require constant recharging remain challenges for this project.

Solution 36: In this research paper, an Internet platform for activating older adults was put forward. However, if an older person is unfamiliar with technologies, computers, and mobile devices, the platform is of no use. Therefore, a human assistant is required to get the platform started.

Solution 37: For the AIBO robot project, an off-the-shelf animal-like robot was provided to assist patients in hospitals where live animals are not allowed. In this case, a bond with the live animal is required. Additionally, the robot requires charging and has limited capabilities, but can still be beneficial.

6.2. Verifying the validity of statistical test

The validity test is 2-fold (see Section 5.2). First, the t-test indicates that the various technology adoption issues identified are statistically significant. For example, according to the statistical analysis, the t-value is bigger than the critical value of t, which is 2.262, at the confidence interval of 95%, degree of freedom of 9, and alpha value of 0.05. This means that technological awareness is statistically significant for older persons' embrace of technology. Moreover, the hypotheses postulated for statistical analysis of other technology adoption issues proved substantial based on the t-test. This means that the identified technology adoption issues should be considered when implementing suitable technologies for the aging population.

Secondly, the correlation analysis further clarifies the relationship between the technology adoption issues identified based on our formulated hypotheses. In addition, the correlation analysis provides evidence of the strength and course of action of the technology adoption issues identified. For example, our correlation analysis revealed a strong statistical relationship between understandability and ease of use based on the value 0.349215 and a p-value of 0.006225. However, we noticed a weak relationship between technological awareness and willingness (readiness) to accept technologies, possibly due to negative feelings about the technology hardware or an inability to operate it. Most profoundly, the correlation analysis revealed that support and improved wellbeing have a moderately positive correlation of 0.5238095, statistically significant at a p-value of 0.1202. This means that supports from Governments or organizations in terms of funding and other motivation will improve the wellbeing of the aging population.

6.3. Reflection and implication

Based on our analysis in Section 5.1, many technical solutions are still at the development stages. Because there is no clear implementation plan and funding, only a small percentage of these solutions are currently being used or are about to be used in real life. Therefore, the governments, providers, developers, etc., should be aware that when introducing a technology to older adults, the key drivers that facilitate its adoption should be considered. Also,

they should be mindful that older adults may not have the necessary knowledge, skills, motivation, or confidence.

In Section 5.2, we used the quantitative approach to establish the technology's suitability for the ageing population. Regarding that, the null hypotheses and alternative hypotheses were formulated. We subjected these hypotheses to a statistical test to verify their validity. For that, the T-test and correlation analysis are used. While the T-test was used to statistically reveal the significant level of technology adoption issues, we used correlation analysis to understand the relationship between the several technology adoption problems that we identified.

The fundamental ways to improve technology adoption by older adults are (i) ensuring the motivational support in using these technologies [81, 82], (ii) creating an extensive awareness of its potential benefits through education and training exercises toward improving the QoL of older adults [83], (iii) ensuring a sustainable plan and measures toward incorporating these technologies into the lifestyles of older adults, (iv) working out a strategy or framework that ensures support by key organizations and their respective management for design and implementation of suitable technologies, (v) building reliable and trustworthy solutions within older adults' competencies to use the technologies, (vi) making the required facilities, such as Internet services, available, and (vii) involving all stakeholders, especially the older adults themselves in the requirements elicitation process to develop an acceptable technical solution [84]. Significantly, a positive attitude toward adopting technologies by older adults can also positively influence their wellbeing.

7. Strengths and limitations

A strength of this study is that many existing technology solutions were analyzed. The analyzed solutions combine different projects, patents, and publications. This technology adoption review provides insight into the negative and positive features of the analyzed solutions for improving the QoL of older adults. Remarkably, the collaborative nature of the review process among the authors was instrumental to understand the current gaps between the needs, provided solutions, and their adoption from different perspectives.

Although the sample size of the respondents used for testing the hypotheses in Section 5.2 was small, still, there was diversity in the gender, age, ICT proficiency, and educational level of the older adults who answered the questions. In a small sample size, heterogeneity could be advantageous because it draws attention to critical features of the phenomena through a pattern across variance [85, 86]. However, as part of our ongoing study, we intend to take into account bigger sample sizes across many nations, not just in Estonia for a more generalized and comparative results.

Another strength of our study is the combination of the TAM and DOI theoretical frameworks, which ensured that we caught pertinent viewpoints regarding analyzing the technology adoption concerns. A qualitative design was used, which made room for new viewpoints in identifying the strengths and weaknesses of each existing solution analyzed. Also, a quantitative method was used, enabling to test and formulate the hypotheses.

There are obviously some drawbacks in this study. First, the sample size used for testing the hypotheses is rather small, which has a detrimental impact on the generalizability of the results. Additionally, the older adults' prevailing circumstances and state of mind when answering the questions may have influenced their narratives and response. This leaves place for future work since a large scale study would bring further benefit to the research community.

8. Conclusions and recommendations

This paper investigated the technological solutions from the technology adoption perspective based on the TAM and DOI technology adoption frameworks using the mixed method research approach. First, our analysis reveals both the positive and negative aspects of using technologies by older adults to improve their QoL. Second, we used a statistical metric to establish the appropriateness of our analysis further. Thirdly, we made an essential contribution based on our in-depth analysis by providing crucial recommendations and policy implications for consideration below in this section.

Consequently, we recommend, as a policy, the full support of governments and private organizations to design and implement holistic solutions. In our opinion, the involvement of governments in driving the campaigns for adopting technologies toward increasing the QoL of older adults is inevitable for successful technology adoption. Support by a government can be implemented in terms of funding and enacting laws that give relevance and attention to the ageing population of a society.

Additionally, we recommend that privacy concerns of older adults should be further considered based on, for example, the framework suggested in Khan and Gambo (87), when implementing any technical solution for improving QoL and wellbeing.

Author contributions

IG, KT, KM, RZ-G, AA, MM, MB-D, FM, and AL: conceptualization and writing—review and editing. IG and KT: methodology and data analysis. IG, KT, KM, RZ-G, AA, MM, and AL: formal analysis and investigation. KT: resources, supervision, and funding acquisition. IG: writing—original draft preparation. KT and KM: project administration. 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.

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Publisher's note

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IoT in medical diagnosis: detecting excretory functional disorders for Older adults via bathroom activity change using unobtrusive IoT technology

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The Internet of Things (IoT) and Artificial Intelligence (AI) are promising technologies that can help make the health system more efficient, which concurrently can be particularly useful to help maintain a high quality of life for older adults, especially in light of healthcare staff shortage. Many health issues are challenging to manage both by healthcare staff and policymakers. They have a negative impact on older adults and their families and are an economic burden to societies around the world. This situation is particularly critical for older adults, a population highly vulnerable to diseases that needs more consideration and care. It is, therefore, crucial to improve diagnostic and management as well as proposed prevention strategies to enhance the health and quality of life of older adults. In this study, we focus on detecting symptoms in early stages of diseases to prevent the deterioration of older adults' health and avoid complications. We focus on digestive and urinary system disorders [mainly the Urinary Tract Infection (UTI) and the Irritable Bowel Syndrome (IBS)] that are known to affect older adult populations and that are detrimental to their health and quality of life. Our proposed approach relies on unobtrusive IoT and change point detections algorithms to help follow older adults' health status daily. The approach monitors long-term behavior changes and detects possible changes in older adults' behavior suggesting early onsets or symptoms of IBS and UTI. We validated our approach with medical staff reports and IoT data collected in the residence of 16 different older adults during periods ranging from several months to a few years. Results are showing that our proposed approach can detect changes associated to symptoms of UTI and IBS, which were confirmed with observations and testimonies from the medical staff.

KEYWORDS

Internet of Things, excretory functional disorders, early detection, irritable bowel syndrome, urinary tract infection, older adults

1. Introduction

Early detection and prevention of health issues are today's major public health challenges facing medical staff and policymakers (1, 2). This situation is more critical for older adults since aging is associated with a serious decline in physical and cognitive abilities, a situation that is emphasized by the poor management of aging-related health problems. Nowadays, existing geriatric services have limited abilities to detect possible health changes and adapt medical assessment and intervention for older adults. Bridging the gap between these geriatric needs and existing services is a major incentive to improve the impact of these services. We argue that detecting older adults' possible health problems as early as possible helps reduce the economic burden on society, improve quality of life for older adults, and promote healthy aging (3, 4).

Technological observations based on the Internet of Things (IoT) and artificial intelligence (AI) are perceived as possible solutions for continuous monitoring and early detection of older adults' health problems. They enable us to collect real-time data and make prompt decisions that help medical staff (e.g., geriatricians) detect health-related problems at an early stage, without the need to perform classical tests (e.g., psycho-geriatric tests) that have limitations including assessment inaccuracies and the difficulty for older adults to recall past events. Therefore, we propose an unobtrusive approach for long-term behavior monitoring and early detection of possible changes in older adults' health status based on IoT and change point detection analysis. These technologies enrich medical observations and enhance medical assessment by providing new objective observations of daily living activities. Additionally, classical methods are insufficient to follow health status daily (5) because they retrospectively approach changes after their occurrences and do not focus on the early detection of changes. In this study, we focused on the early detection of digestive and urinary system disorders in older adults. Approximately 10%−15% of older adults are estimated to develop irritable bowel syndrome (IBS) in developed countries (6), numbers that can increase to 45% in underdeveloped countries (7). As for urinary tract infections (UTIs), ∼2% of the world's population develops this condition every year (8).

Our approach proposes a way to detect changes in a subject's bathroom activity behavior. However, our method does not assess the cause underlying this behavior change. It was only following the medical staff's assessment of our results that we were able to associate our results with a UTI.

2. Background

The human excretory system is responsible for removing excess undesirable material, usually fluids and solids, from the body to ensure the body continues to work efficiently. The human excretory system is composed of multiple subsystems, each of which is responsible for getting rid of a particular form of body waste. The urinary and digestive systems are subsystems that are part of the excretory system. The urinary system is responsible for filtering blood and excreting excess water and salts as urine (9). As for the digestive system, it is responsible for getting rid of indigestible food particles in the form of solid feces through defecation (10). IBS and UTIs are among the known problems of the human excretory system.

IBS is a disorder that can occur in the large intestines, a part of the digestive system. The most common symptoms associated with IBS include abdominal pain, usually associated with bowel movements, nighttime diarrhea, and constipation. IBS usually occurs in people 50 years old or older (11).

UTI is a disorder that occurs in the urinary system. Symptoms may include sudden changes in urinary habits (such as increased frequency or urgency), pain or burning while urinating, and pain or tenderness in the pelvis, lower back, or abdomen (12). Untreated UTIs can spread from the bladder to the kidneys and beyond. As such, treating a UTI early can keep it from spreading and overwhelming the immune system, especially in older adults or anyone with a deficient immune system (13). UTI is one of the most commonly diagnosed infections in older adults. It is the most frequently diagnosed infection in long-term care residents, accounting for over a third of all nursing home-associated infections (14, 15). It is second only to respiratory infections in hospitalized patients and community-dwelling adults over the age of 65 (16, 17).

As our population ages, the burden of IBS and UTI in older adults is expected to grow simply because there is an increased number of older adults in the population, resulting in the need to improve diagnostic, management, and prevention strategies; elements that are critical to enhancing the health of older adults. As a first step to accomplishing this goal, we need to improve the follow-up of the overall bathroom activity of older adults to gain a better understanding of their general bathroom behavior. Hence, in the present study, we propose an unobtrusive IoT system to monitor the overall bathroom behavior of older adults inside their residences, which will enable us to detect unusual emerging behaviors across their overall bathroom behavior.

3. Related work

There are multiple scales and tests (e.g., psycho-geriatric) in medical science that analyze older adults' behavior and detect possible health changes. Among these scales, the Short Emergency Geriatric Assessment (SEGA) evaluates the frailty of older adults (18), the Mini-Mental State Examination (MMSE) targets cognitive changes, such as orientation problems, attention difficulties, and language troubles (19), the Geriatric Depression Scale (GDS) investigates changes in mood and emotions; e.g., sadness, sedentary life, and depression (20), the Instrumental Activities of Daily Living (IADL) identifies changes in activities of daily living associated with autonomy loss (21), and the Mini Nutritional Assessment (MNA) investigates nutritional changes, such as eating difficulties, weight loss, and protein intake insufficiency (22).

While these medical scales and tests help medical staff (e.g., geriatricians) analyze and evaluate older adults' behavior and identify possible health problems, there are limits to their efficiency. For example, it is inconvenient for older adults to recall past events in full detail at the time of an assessment (23). Therefore, subjective information and missing details might influence assessment results (24). Often, it is also impractical for older adults to move to

a specific location to get an assessment (25). In addition, the assessments require older adults to reply to a given set of questions or perform specific tasks, which may have a negative impact, such as anxiety, if they are unable to reply to some questions or perform some tasks. Therefore, medical staff would benefit from using additional means to gather more thorough and complete objective observations to complete their medical assessment. In this respect, IoT monitoring technologies can be used to closely follow older adults in their living environment (e.g., at home), to detect possible health changes early (26).

IoT technologies offer portable devices, and medical equipment that can be used to gather data on patients, identify diseases, keep track of the patient's health, and send out notifications once a medical emergency is detected. These solutions include a variety of technologies, such as electrocardiogram (ECG) and pneumography monitoring systems (27–29), glucose level monitoring solutions (30, 31), temperature monitoring solutions (32, 33), and blood pressure monitoring systems (34–36). IoT technology can be used to detect short-term health problems, e.g., Aloulou et al. (37) deployed movement, pressure, proximity, and vibration sensors in nursing home rooms to detect night wandering and toilet falls. Semantic reasoning rules recognize the activities of daily living in real time and notify formal caregivers about potential anomalies. Rantz et al. (38) used motion and bed sensors to track movement, pulse, breathing, and bed restlessness to retrospectively detect health changes. Following the occurrence of significant health events, geriatricians review the monitoring data to investigate possible correlations. Another study (39) focused on sleep monitoring, as a lack of sleep may increase the risk of cognitive decline in older adults. A remote and non-intrusive technology was proposed to help patients monitor their sleep at home. A sensor mat equipped with an integrated micro-bending multimode fiber was deployed and evaluated in a free-living environment. The study enabled researchers to analyze the participants' sleep quality using various parameters deduced from the sensor mat. Vital signs, namely heart rate, respiratory rate, and body movements, were also reported to detect abnormal sleep patterns. Sensory observations have helped care-focused medical staff focus on areas that require more detailed attention, confirm their medical assessments, and detect patterns of decline not usually detected during regular office visits. A complete technical review for sleep cycle monitoring is conducted by the same authors afterward in Siyanbade et al. (40).

Based on AI technologies, other solutions were proposed to detect mental health problems, depression, stress, and bipolar disorder. In the study proposed by Alam et al. (41), a convolutional neural network (CNN) was used to analyze and classify a person's mood into six different categories: happy, thrilled, sad, calm, distressed, and angry. An advanced machine learning system was also adopted by Pandey (42) to identify stress periods in advance using heart rate. The proposed solution informs the patient about their stress level and prevents accidents. Similarly, Zekri et al. (43) were interested in detecting older adults' behavior changes. In their study, they modeled older adults' behavior and defined the normal behavior of a person as a sequence of four activities (sleeping, eating, taking a shower, and leaving home). An unsupervised approach based on the density-based

clustering (DBSCAN) algorithm was applied, and the deviations were detected by computing a similarity score between the current behavior of the older adult and her/his normal behavioral pattern. Another study (44) applied deep learning methods, including CNNs and extreme learning machines (ELMs), to differentiate between ballistocardiogram (BCG) and non-BCG signals. BCG signals were collected using an IoT-based micro-bend fiber optic sensor mat from 10 patients with obstructive sleep apnea. The study used three methods to balance the number of BCG and non-BCG signals, including undersampling, oversampling, and generative adversarial networks (GANs). The system's performance was evaluated using 10-fold cross-validation, and the best results were obtained using CNN-ELM with GANs as the data balancing method. The results showed an average accuracy, precision, recall, and F-score of 94%, 90%, 98%, and 94%, respectively. Furthermore, the study presented by Sadek et al. (45) focused on contactless monitoring of heart rate (HR) using under-mattress (BCG) sensors. The authors studied the potential of two wavelet-based methods, the multiresolution analysis of the maximal overlap discrete wavelet transform (MODWT-MRA) and continuous wavelet transform (CWT), for HR detection using a microbend fiber optic sensor (MFOS). BCG signals were collected from 10 sleep apnea patients during an overnight polysomnography (PSG) study, and the MFOS was placed under the bed mattress. The PSG electrocardiogram (ECG) signals were used as a reference to evaluate the proposed HR detection algorithms. The results showed that the CWT with a derivative of Gaussian (Gaus2) provided slightly better results compared to the MODWT-MRA, CWT (frequency B-spline), and CWT (Shannon). However, the total precision for MODWT-MRA was higher than Gaus2.

As previously detailed above, IoT sensor observations can help care-focused medical staff in their practice. However, we could not find other technological solutions in the literature that help match observations with UTI and IBS symptoms. In this field, the gold standard to diagnose UTI and IBS includes (1), for UTI, lab screening through urine sample analysis, and (2) for IBS, stool tests. Moreover, healthcare providers are likely to evaluate IBS with a complete medical history and a physical exam and try to match symptoms with the IBS definition. They may also run tests to rule out some other possible causes of these symptoms. In our approach, we argue that an IoT system can be used as an aiding technological tool to follow-up on health status (including UTI and IBS) by following subject activity, in this research, in the bathroom.

In our research, an IoT system, which encompasses motion sensors to detect the participant's movement inside the bathroom, is used along with conventional statistical methods to monitor and detect the change in the overall bathroom behavior of individual participants. As in our previous research, where we monitored and identified behavior change on a granular level, that is, activity (and sub-activity) levels were evaluated daily [e.g., (46–48)], this research focused on high-level behavior change detection. However, in the present study, the goal is to show that reporting triggers to healthcare professionals (based on behavior change detection), it enables them to be more efficient and offer better health follow-up. Moreover, we presented the ability to impute the missing data found along with the collected data at any missing rate. Furthermore, the level of analysis we propose here requires fewer

TABLE 1   Relevant information about participating subjects in the France experiment.

Subject code	Gender	Age	Monitoring period	
			Start	End
A	M	90–94	2014-09-23	2015-02-13
B	M	90–94	2015-03-15	2015-08-03
C	M	80–84	2015-09-10	2018-11-30
D	F	85–89	2014-09-23	2015-08-06
E	F	95–99	2015-08-13	2018-11-30
F	F	85–89	2014-09-23	2017-01-18
G	F	90–94	2014-09-23	2018-11-30
H	F	95–99	2014-09-14	2015-06-03
I	F	95–99	2015-06-04	2018-11-30
J	F	90–94	2014-11-24	2015-10-12
K	M	85–89	2016-10-11	2017-01-30
L	F	90–94	2017-04-04	2018-11-30
M	M	90–94	2016-10-11	2018-11-30
N	F	90–94	2016-10-11	2018-11-30
P	F	90–94	2017-04-07	2017-06-15
V	M	65–69	2017-10-20	2018-11-30

FIGURE 1
Schematic description of the bathroom with the spatial location of sensors.

FIGURE 2
Sensor signal values for a snapshot of activity.

sensors as well as less installation and maintenance costs. Put simply, the system we present here is more economically viable and can be used to monitor patients for long period with minimal cost. In addition, working at this high level requires less computation, since we do not need to follow/detect precise activities. In our case, we do not need to analyze the details of bathroom visits to trigger the alerts. If we analyze changes in the overall number of bathroom visits, we obtain the same result.

4. Methodology

Our methodology is based on three pillars: (1) real-time data collection in the subjects' environments, (2) adapted data analysis based on custom algorithms and visualization tools, and (3) results validation with caregivers.

4.1. Data collection

The data we used to illustrate our methodology were gathered through an infrastructure that covers all the IoT layers (49). The infrastructure (50) was deployed in the real-life studio residences of 16 older adults for periods ranging from several months to a few years in France (51). The subjects' codes, along with their gender, age class, and the monitoring duration, are presented in Table 1.

Bathroom activity was monitored around the clock using an infrastructure mainly based on motion sensors mounted in the participants' bathrooms. These motion sensors are mounted so that they can capture motion over the sink and the toilet area of
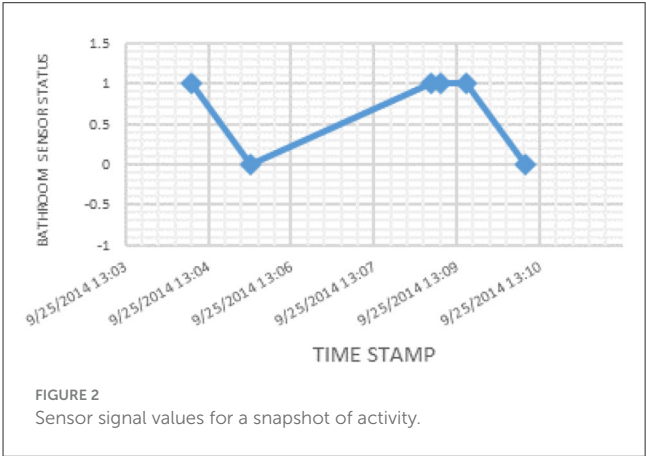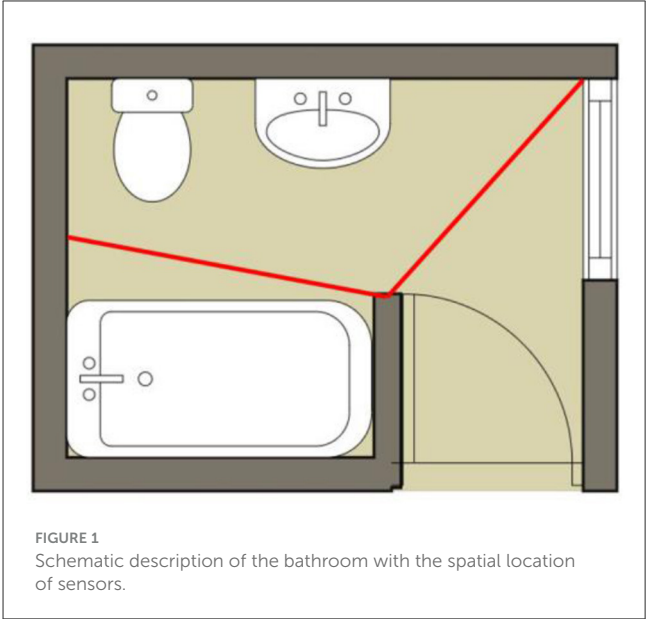
each bathroom. A schematic of the bathroom describing the spatial location of the sensor is presented in Figure 1. In each washroom, we used Wyze Sense motion sensors with a 120° field of view and a range of approximately 8 meters. These sensors are characterized by an adjustable relaxation time ranging from 5 s to 15 s.

The presence of an older adult inside the bathroom is recorded by the sensor as a logic signal of 1, while the absence is recorded as a logic signal of 0. The corresponding sensor signal values for a snapshot of activity are presented in Figure 2. The details of the deployment experiment can be found in Kaddachi et al. (50, 52).

4.2. Data analysis

The proposed algorithm was first used to calculate overall daily bathroom activities and to define daily living patterns. From the overall daily activity, we thus focus on the whole objective excretory function. In this study, we use conventional mathematical methods to identify the change points across the time series.

A pre-processing algorithm was used to convert the raw logic signal data into an overall daily bathroom activity, while a post-processing algorithm was used to identify the timestamps at which behavior changes occurred. The pre-processing and post-processing algorithms are presented in Algorithms 1, 2, respectively.

Prior to applying the pre-processing algorithm, we imputed missing data using our novel Bayesian Gaussian Approach (BGaP) (53). The missing data type found in our collected subjects' data was considered to be missing completely at random (MCAR), which assumes that the missingness of the data presents no correlations to any potential variables structuring the time series (53). The imputed subject's activity time series was then normalized to the complete number of hours per day, i.e., the resulting pre-processed bathroom activity time series represents the average number of bathroom visits per hour in a day. This is an essential step to compare the bathroom activity for all subjects together.

The two algorithms were used iteratively to identify and retrieve changes in activities in the overall daily bathroom activity and to identify the associated time at which such changes occur. Specifically, Algorithm 2 defines a Pruned Exact Linear Time (PELT) technique applied to the overall daily bathroom activity data that was used to identify the predicted change points. PELT technique is a method for detecting change points in a time series; it is an efficient and exact algorithm for change point detection, meaning that it provides an exact solution and is computationally efficient, making it well-suited for large datasets. It is also a "pruned" algorithm, which eliminates unnecessary calculations to improve computational efficiency. The PELT technique works by considering a sliding window of the time series and calculating a cost function that measures the difference between the current window and the previous window. If the cost function exceeds a certain threshold, a change point is identified. The process is repeated for each window in the time series, and the change points are identified as the points where the cost function exceeds the threshold. One advantage of the PELT technique is its ability to handle multiple change points in the time series, making it well suited for datasets with complex patterns. Additionally, the algorithm can easily be adapted to different types of cost functions, allowing for the detection of different types of change points.

4.3. Validation

The validation of our results was based on observations from collaborating medical staff (doctors, caregivers, and nurses), as well as the feedback from our iterative meetings. We have collaborated with two caregivers from a nursing home and one geriatrician for individual participants.

The caregivers recorded all significant observations daily and continuously collected electronic health records. Individual participants have monitored via

```
Input: a path to Subject's Sensors' Raw Data
       file, e.g., Raw_A.csv
Output: daily Overall Bathroom Activity
        DataFrame
1    Initialization of variables: assign zero to
all variables
2    Set Subject_DataFrame ← subject.csv
3    Set Subject_DataFrame Index ← Date
4    Extract Bathroom Sensor Raw Data to a new
dataframe:
5  DataFrame_Sensor_Bathroom ← Subject_DataFrame;
where Subject_DataFrame (Sensor) ==
(Sensor_Bathroom_ID)
6    Convert Bathroom Sensor Raw Data to Binary
Format:
7  for each entry in DataFrame_Sensor_Bathroom:
8      if (DataFrame_Sensor_Bathroom == 'on'):
9          DataFrame_Sensor_Bathroom (entry) = 1
10     else:
11         DataFrame_Sensor_Bathroom (entry) = 0
12     End
13 End
14   Calculate Subject Daily Overall Bathroom
  Activity:
15     Construct time vector between first index and
       last index in DataFrame_Sensor_Bathroom:
16         start ← DataFrame_Sensor_Bathroom.index[0]
           end ← DataFrame_Sensor_Bathroom.index[-1]
           time_vector ← date_range(start, end)
17      Calculate Bathroom_Count:
18      Set Bathroom_Count ← empty for each item1
        in time_vector:
19          temp1 ← zero
            temp2 ← empty
            temp3 ← zero
            temp4 ← zero
            derivative ← empty
20          for each item2 in DataFrame_Sensor_Bathroom:
21              if (time_vector[item1] ==
                DataFrame_Sensor_Bathroom[item2]):
22              temp1 ← DataFrame_Sensor_Bathroom[item2]
                temp2 ← append temp1 to temp2
23              End
24          End
25          for each item3 in temp2:
26              temp3 ← temp2[item3 - 1] - temp2[item3]
27              derivative ← append temp3 to derivative
28          End
29          for each item4 in derivative:
30              if (derivative[item4] < zero):
31                  temp4 ← temp4 + 1
32              End
33          End
34      Bathroom_Count ← append temp4 to Bathroom_Count
35   Set Daily_Overall_Bathroom_Activity_DataFrame
   ← time_vector, Bathroom_Count
```

Algorithm 1. Daily overall bathroom activity calculation.

```
     Input: a path to Subject's Daily Overall
   Bathroom Activity file, e.g., Case_A.csv.
     Output: data frame of change value and
   corresponding change date.
1    Initialization of variables: assign zero to
   all variables
2    Subject_DataFrame ← subject.csv
3    Set Subject_DataFrame Index ← Time Stamp
4    Extract Bathroom Activity/Hour
   from Subject_DataFrame:
   Activity_per_hour
   ← Subject_DataFrame(Bathroom_Hour)
5    Initialize PELT algorithm parameters:
6    Input ← Activity_per_hour
     Output ← Change_Locations
7    Model ← autoregressive
     Jump_size ← 5
     Min_size ← 2
     Penalty ← 0.01
8    Retrieve Change Dates
9    Set change_dates ← zero
10   for each change_location in change_locations:
11       temp ← Subject_DataFrame.index ==
         change_location - 1
12       change_dates ← append temp to change_dates
13   End
14   Retrieve Change Values
15   Set change_values ← zero
16   for each change_date in length of change_dates:
17       temp ← Subject_DataFrame.index == change_date
18       change_values ← append temp(Bathroom_Hour) to
         change_values
19   End
20 Set Changes_DataFrame ← change_dates,
   change_values
```

Algorithm 2. Daily overall bathroom activity anomaly detection.

nurse visits. These nurses' visits monitored participants a few times per day for medicine taking, toilet entry assistance, room cleaning, and nutritional services. Nurses reported all interventions, formal and informal observations, special health events, and social habits in developed software. These electronic health records include geriatric assessment results, hospitalizations, treatments, and physical, emotional, and cognitive problems.

In addition, regular review meetings allowed for accurate investigation of possible causes of detected changes and any health problems associated with them. These meetings were planned with older adults, family members, and family doctors (each for 4 months with a nursing home and each for 2 months with individual houses). Medical staff evaluated the medical relevance of investigated change explications by reviewing all past detected changes and correlating them with medical records (e.g., geriatric scales, cognitive diagnosis, and prescribed treatments).

5. Results and discussion

Following, we present the results of our algorithms applied to the bathroom activities of the different participants from two different perspectives.

- First, we present the time series of the bathroom activity after imputation for the entire monitoring period for each participant, where we highlight the time of the detected changes as a result of the PELT algorithm by a vertical red line (Figures 3–9 and Supplementary Figures 1–9), each vertical red line along the overall bathroom activity time series represents a change in the participant's bathroom behavior in comparison with the preceding window of calculation, where this change represents either an increase or a decrease in the number of the subject's bathroom visits. *We claim that changes caused by an increase in bathroom visits are due to the participant experiencing an UTI.*
- Second, we presented a heatmap illustrating the entire bathroom activity for each subject day by day. This representation helped the medical staff compare the subject's bathroom activity across different months of the year and, hence, during the entire monitoring period. In addition, with the aid of the heatmap (Figures 10–15 and Supplementary Figures 10–19) the physician can easily pinpoint the day when the highest number of bathroom visits occurred, leading to a feasible identification of the UTI.

It is worth mentioning that the heatmaps are shown without imputation, while the bathroom activity time series are presented after imputing the missing data, in order to prevent misleading visual results by the physicians.

5.1. Time series representation

For subject A, the bathroom activity of the monitoring period extended from late September 2014 to the beginning of February 2015, where we can notice that the subject has four (4) groups of bathroom activity behavior change, as presented in Figure 3.

- First group is found in the second half of October 2014, when the subject experienced a behavior change as an increase in bathroom visits at the end of the first half of October. After this, the subject had a second behavior change, which presented itself as a decrease in his bathroom visits, followed by a third change presenting an increase in bathroom visits. The fourth change is composed of another increase in bathroom visits, and another change on the first of November was also due to an increase in bathroom visits.
- Second group of changes is found in mid-November 2014, showing a positive inflection point of the subject's bathroom activity, meaning that the subject had an increasing behavior of bathroom activity followed by a decreasing behavior. This group consisted of three behavior change timestamps: the first one indicating increasing activities, and the other two indicating decreasing activities.

FIGURE 3
Bathroom activity time series for subject A, with detected change time stamps overlapped as vertical lines.
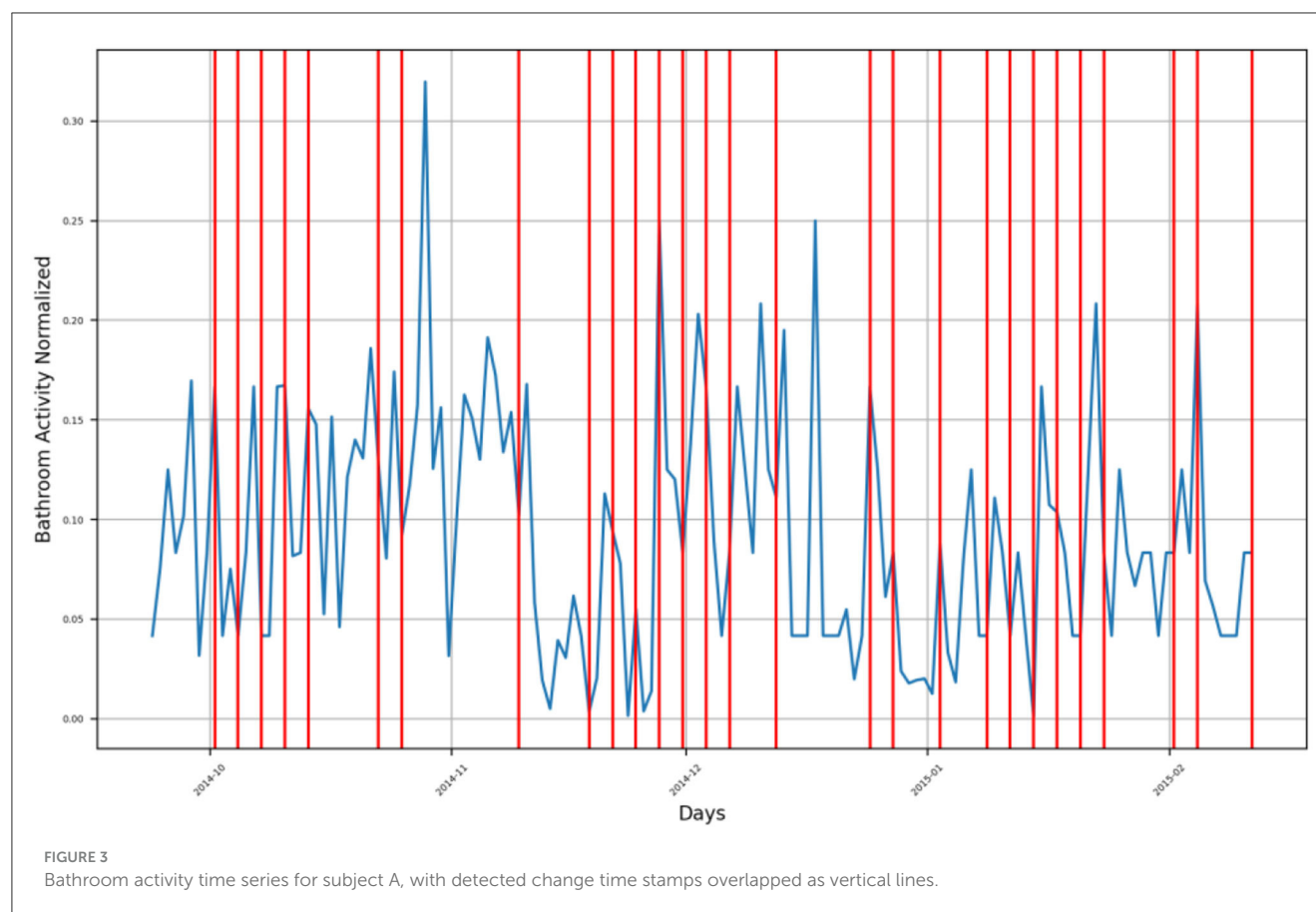
- Third group of changes is found in the first half of December 2014, where the first change, as well as the second one, indicates a decrease in bathroom visits, while the third one indicates an increase in bathroom visits.
- Fourth group of changes is found in the second half of December 2014 and during the first week of January 2015, where changes in timestamps indicate a decrease in bathroom visits. The last group is found in the second half of January 2015 and during the first week of February 2015, where changes indicate an increase in bathroom visits.

Both the second group and the third group form an envelope around a sharp increase in the subject's bathroom activity in the last week of November 2014. Similarly, both the third and fourth groups form an envelope around another sharp increase in the subject's bathroom activity in mid-December 2014.

For subject B, the monitoring period extended from mid-March 2015 to the beginning of August 2015, where there are three groups of bathroom activity behavior changes, as presented in Figure 4.

- First group consists of four change timestamps around mid-April 2015, indicating a decrease in the subject's bathroom visits.
- Second group consists of six change timestamps spread along June 2015, where the first one indicates a decrease in the subject's bathroom visits, while both the second and the third one form an envelope around a changing timestamp

indicating an increase in bathroom visits. The last three change timestamps indicate a decrease in bathroom visits.
- The last group consists of a single change timestamp indicating an increase in bathroom visits by the subject and is located on 2 August 2015.

Both the third group and the fourth group form an envelope around a sharp increase in the subject's B bathroom activity located in mid-December 2014.

For Subject C, several groups of bathroom activity changed timestamps across the monitoring period, which extended from October 2015 to January 2018, as presented in Figure 5.

- The first group of behavior changes is located between October 2015 and January 2016, where bathroom activity behavior increased. In March 2016, a decreasing trend of bathroom visits was found, while another decrease in his bathroom visits was detected in May 2016. The subject's behavior started to increase again during the period extending from July 2016 to December 2017, where six detected behavior change timestamps occurred over this period, all of them representing the behavior change toward an increase in the subject's bathroom visits. A sudden decrease in the bathroom activity of the subject was detected in late January 2017, and another decrease in his bathroom activity was detected in March 2017 as well. Additional two-bathroom activity changes were detected in late May 2017 and on the first week of June

FIGURE 4
Bathroom activity time series for subject B, with detected change time stamps overlapped as vertical lines.
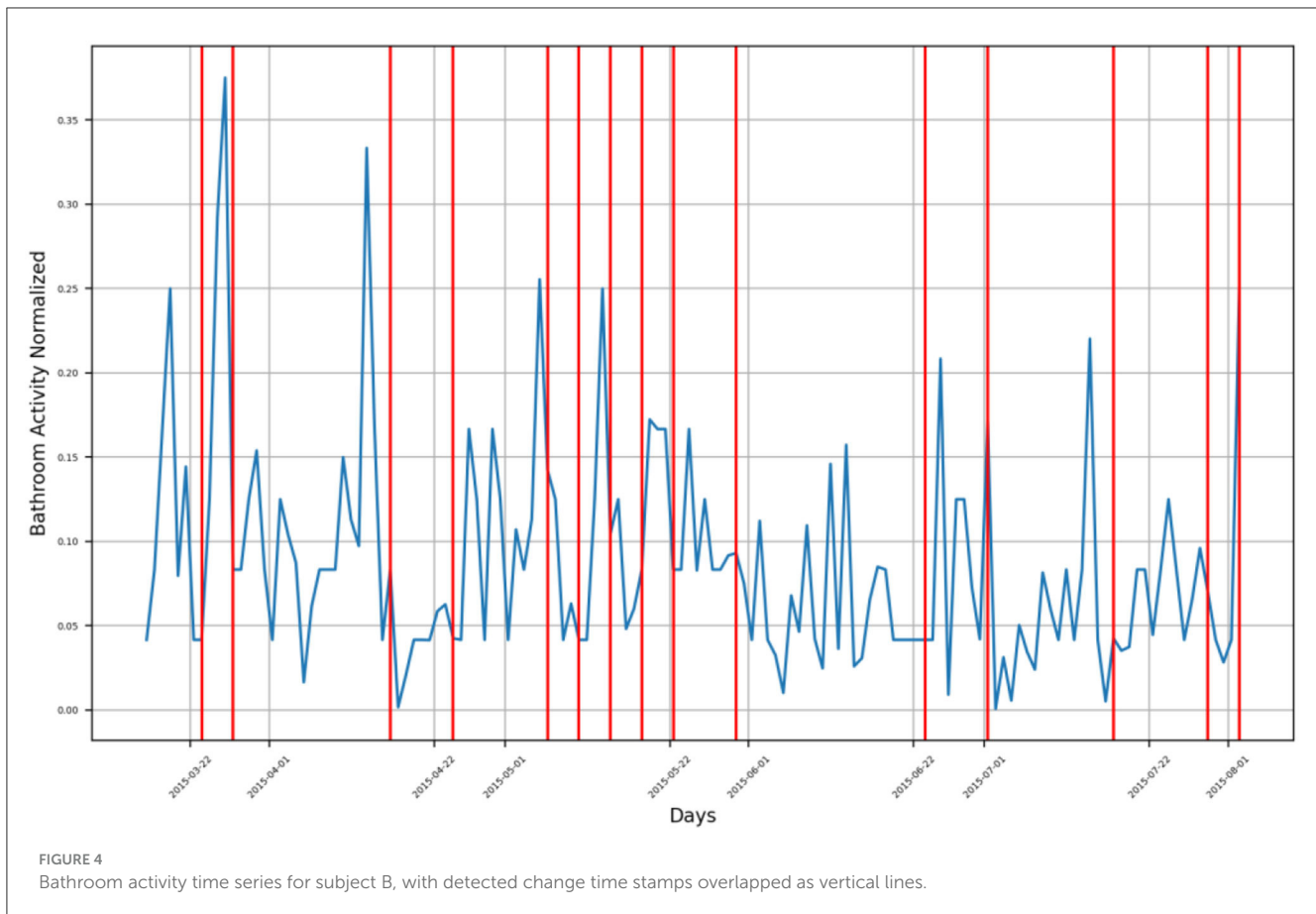
2017. A decreasing behavior in the subject's bathroom activity behavior was detected by three change timestamps between July 2017 and August 2017.

- Following, a period of increasing bathroom activity was detected by a group of change timestamps extending from October 2017 to November 2017, after which a sharp decrease in bathroom activity was detected in December 2017.
- A last group of change timestamps indicating a fluctuation in bathroom activity was found in January 2018.

For subject D, the monitoring period extended from late September 2014 to August 2015, as presented in Figure 6. There are multiple groups of detected behavior change timestamps:

- First group includes a single change timestamp indicating a sudden increase in the number of bathroom visits in the first week of October 2014.
- Second group consists of three change timestamps representing a decrease in bathroom activity during November 2014, where the first timestamp represents a sharp decrease in bathroom activity, while the other two timestamps represent a slow decreasing trend of his bathroom activity.
- Third group consists of two change timestamps indicating a mild change in bathroom activity, one representing a mild decrease and the other representing a mild increase, both found in late December 2015.

- Fourth group consists of two change timestamps indicating an increase in bathroom activity were found in the first week of February 2015. A single change timestamp representing a decrease in bathroom activity is in the first week of March 2015.
- Fifth group consists of two change timestamps at the beginning of April 2015, representing a sharp increase in the subject's bathroom visits.
- Sixth group: a sudden increase in bathroom visits was found in mid-May 2015.
- Seventh group: the last group consists of two change timestamps indicating an increase in bathroom activity located in mid-July 2015 and at the beginning of August 2015.

For subject E, bathroom activity was monitored from October 2015 to January 2018, as presented in Figure 7.

- First group: during the period extending from late September 2015 to late March 2016, the subject is showing an exponential growth trend in his bathroom activity behavior, within which there are two detected behavior change timestamps, first in late September 2015 and second in late December 2015. After this exponential growth period, there is a sharp decrease in the subject's bathroom activity in the last week of March 2016 that is

FIGURE 5
Bathroom activity time series for subject C, with detected change time stamps overlapped as vertical lines.
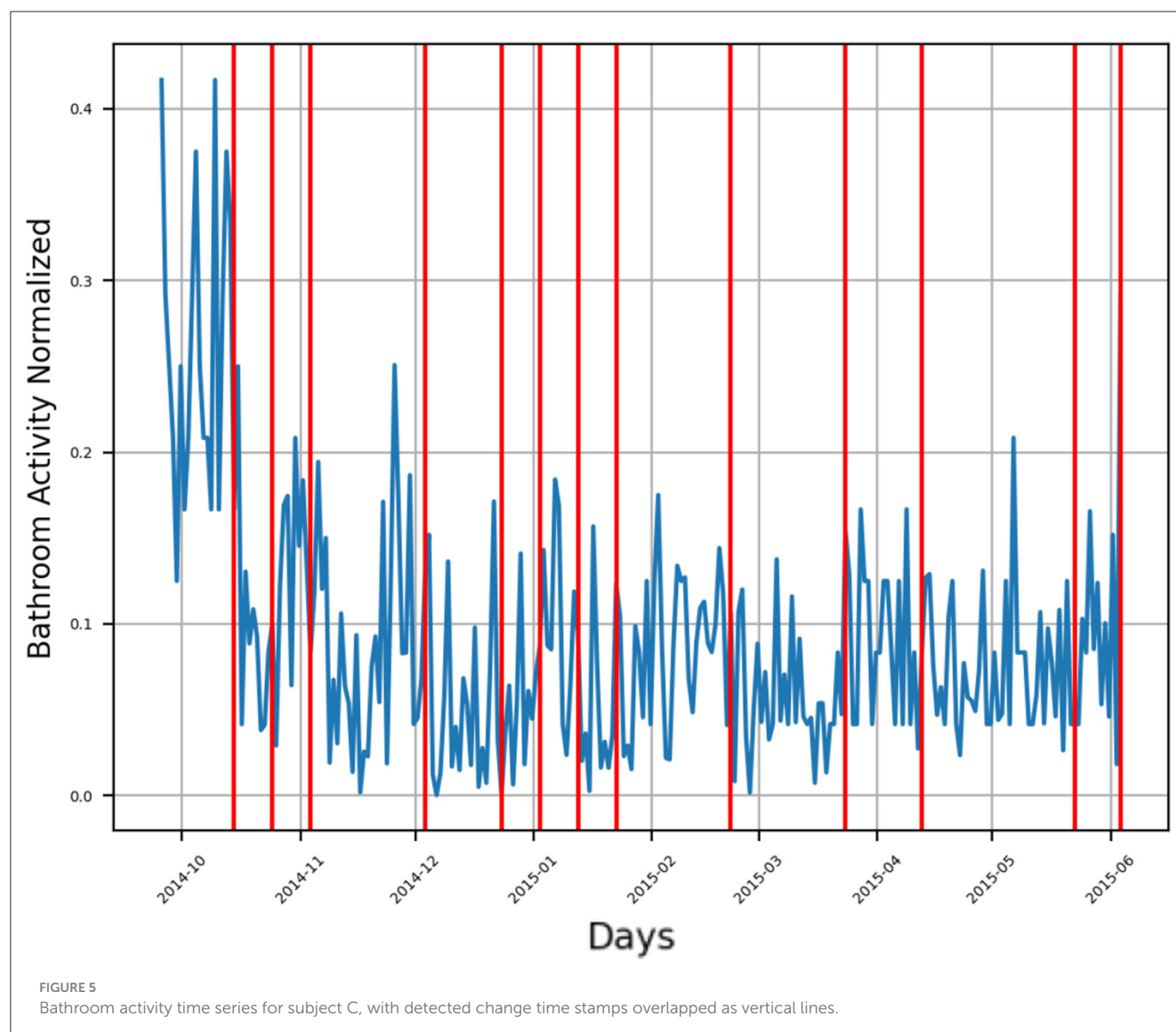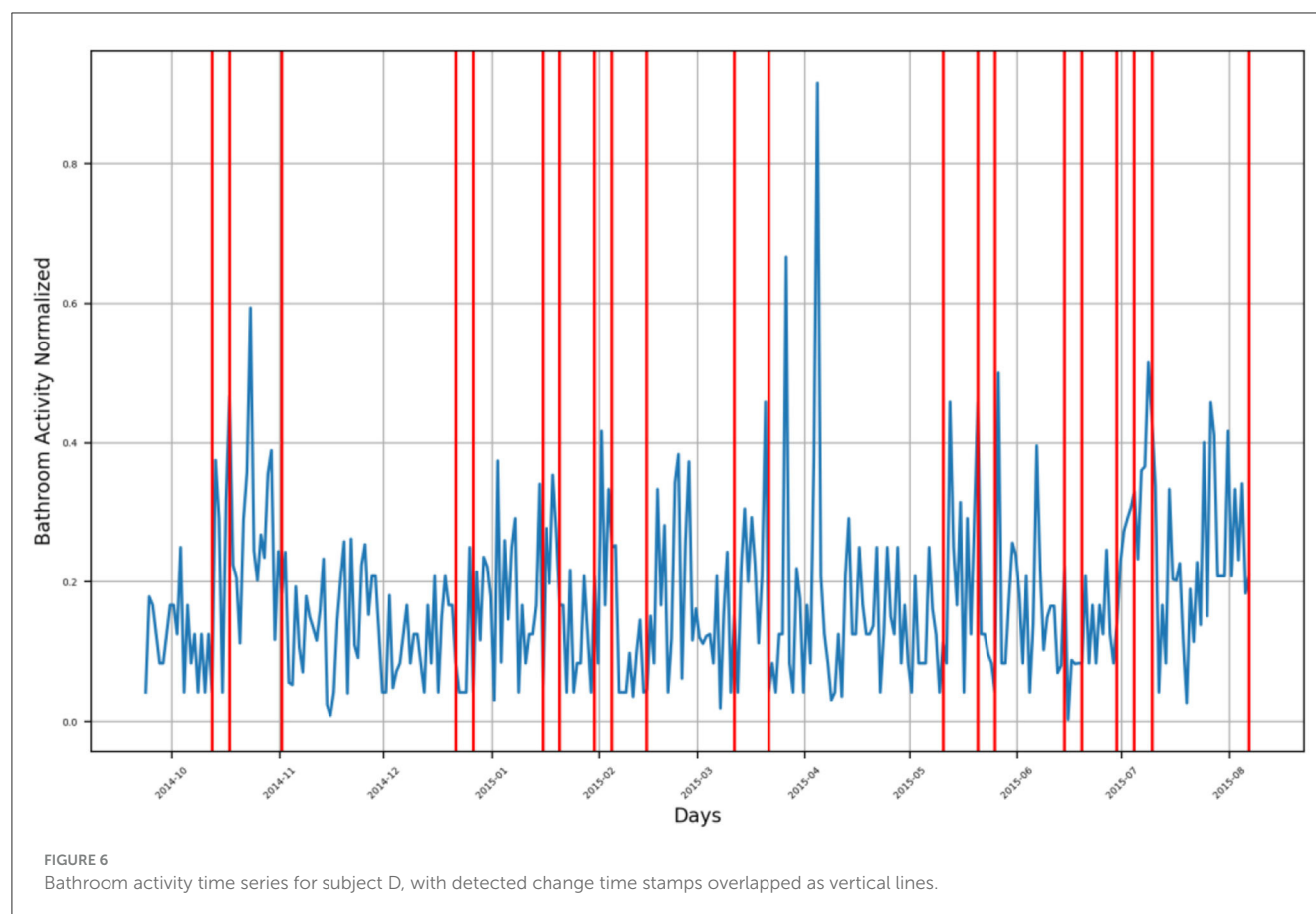
detected by two change timestamps as an envelope around that week.

- Second group: exponential growth trends in the subject's bathroom activity were found between October 2016 and November 2016, where there are multiple detected change timestamps indicating an increase in activity.
- Third group: an increasing trend in bathroom activity was observed from February 2017 to May 2017, after which there was a mild decrease in the subject's bathroom activity until the end of the monitoring period in January 2018.

For subject F, bathroom activity was monitored from October 2014 to January 2017, as presented in Figure 8. During this period, there were three main segments of behavior,

- First segment extends from October 2014 to October 2015, during which the activity is neither following an increasing trend nor a decreasing trend; instead, multiple spikes are indicating a sharp increase in bathroom activity.
- Second segment extends from November 2015 to March 2016, where there is an exponential increase in the subject's bathroom activity followed by a decreasing trend extending from March 2016 to May 2016. There were multiple spikes of sharply increased bathroom visits that were also detected during this segment.
- Third segment: the last segment extends from June 2016 to the end of the monitoring period in January 2017. It represents an increase in the subject's bathroom activity.

For subject G, the monitoring period extended from late December 2015 to January 2018, as presented in Figure 9, where the subject's bathroom activity behavior

FIGURE 6
Bathroom activity time series for subject D, with detected change time stamps overlapped as vertical lines.

follows a cyclic pattern. There are multiple segments of behavior decrease:

- First segment was found in late December 2015.
- Second segment spanned from April 2015 to September 2015.
- Third segment was found in late October 2015.
- Fourth segment was found in late March 2016 and late May 2016.
- Fifth segment was found in September 2016 and from October 2016 to the end of November 2016.
- Sixth segment spans from December 2016 to March 2017.
- Seventh segment was found from May 2017 to September 2017 and from December 2017 to January 2018.

Other segments are representing an increasing bathroom activity behavior.
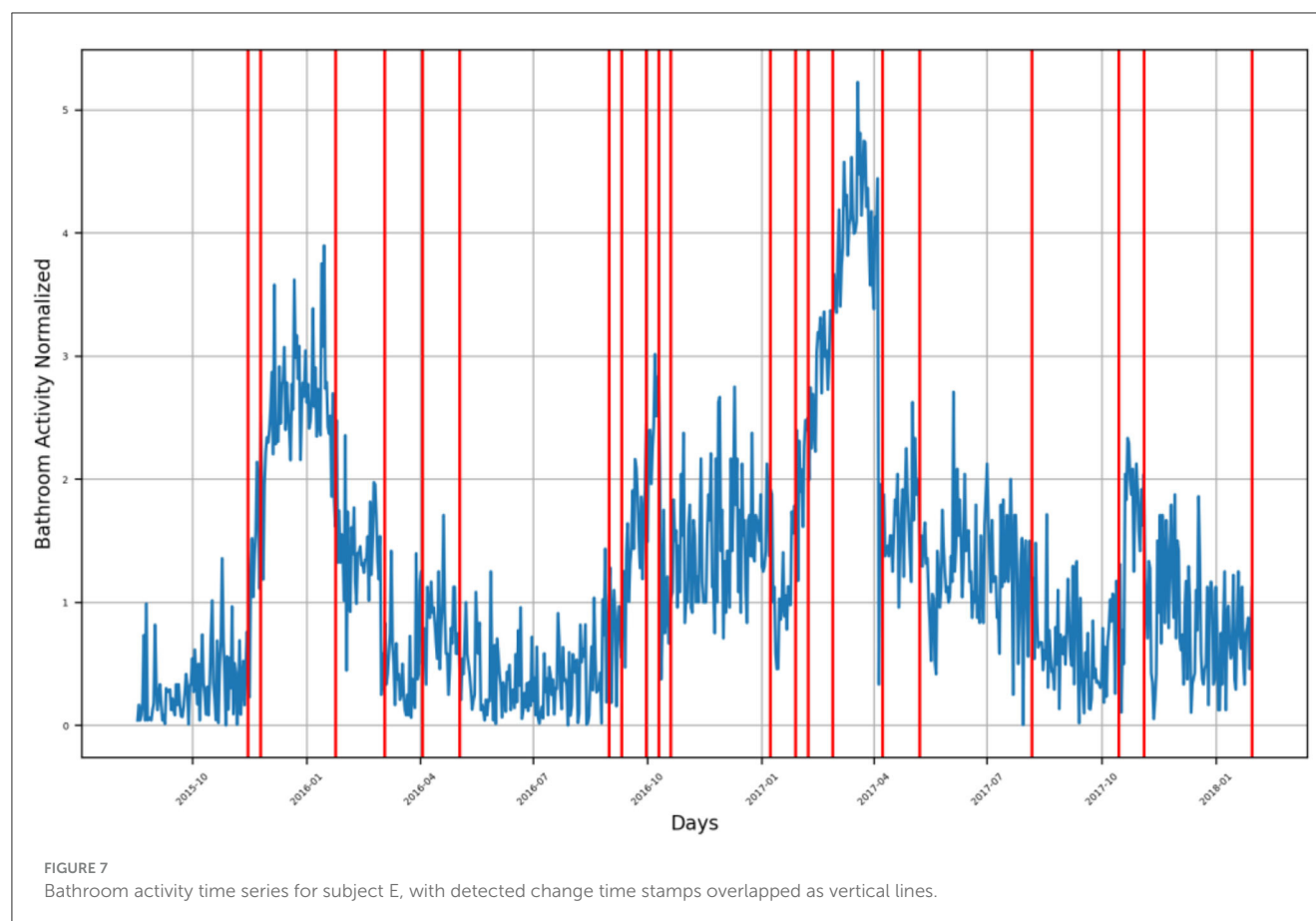
For subject H, the monitoring period extended from late September 2014 to June 2015, as presented in Supplementary Figure 1.

The general subject's behavior represented a decreasing bathroom activity behavior, among which there were multiple sharp increase in bathroom visits. Through the decreasing segment, there were two detected change timestamps in mid-October 2014 and early November 2014. During the few sharp increases in visits, there were six detected change timestamps in mid-December 2014, early January 2015, late March 2015, late April 2015, and early June 2015.

For subject I, the monitoring period extended from May 2015 to January 2018, as presented in Supplementary Figure 2. The subject's bathroom behavior represents cyclic behavior like that of the subject's **G**. The decreasing segments throughout the monitoring period are as follows:

- First segment represents a sharp decrease in bathroom activity compared to the surrounding normalized bathroom activity and was found in June 2015.
- Second segment represents a sharp decrease and was found in September 2015 and October 2015.
- Third segment represents a mild decrease in bathroom activity and extends from late October 2015 to March 2016.
- Fourth segment represents a mild decrease and spans from June 2015 to September 2015.
- Fifth segment represents a slow decrease and extends from January 2017 to April 2017.
- Sixth segment represents a sharp decrease in the subject's bathroom activity and spans from May 2017 to June 2017.
- Seventh segment represents a very sharp decrease in the subject's bathroom activity and was found at the beginning of December 2017.
- Eighth segment represents the last decreasing behavior segment found at the beginning of January 2018.

Otherwise, the subject was showing increasing behavior in his bathroom activity.

FIGURE 7
Bathroom activity time series for subject E, with detected change time stamps overlapped as vertical lines.

For subject F, bathroom activity was monitored from October 2014 until January 2017, as presented by Figure 8. During this period, there were 3 main segments of behavior,

- First segment extends from October 2014 until October 2015, during which the activity is neither following an increasing trend nor a decreasing trend, instead, there are multiple spikes indicating a sharp increase in bathroom activity.
- Second segment extends from November 2015 until March 2016, where there is an exponential increase in the subject's bathroom activity followed by a decreasing trend extending from March 2016 to May 2016. There were multiple spikes of sharply increased bathroom visits which were also detected during this segment.
- Third segment: The last segment extends from June 2016 until the end of the monitoring period in January 2017, it represents an increase in the subject's bathroom activity.

For subject J, the monitoring period extended from late November 2014 to October 2015, as presented in Supplementary Figure 3.

The detected behavior change timestamps indicating an increase in bathroom activity were found in mid-January 2015, at the beginning of February 2015, in late March 2015, in mid- and late May 2015, at the beginning of June 2015, and during the first half of September 2015. Otherwise, the

remaining detected change timestamps represent decreasing bathroom activity behavior. Furthermore, the bathroom activity behavior of the subject showed a cyclic pattern starting in February 2015 and lasting until the end of the monitoring period.

For subject K, the monitoring period extended from October 2016 to February 2017, as presented in Supplementary Figure 4. There are only a few detected bathroom activity behavior change timestamps spread over the monitoring period:

- The detected change timestamp on 15 October 2016 represents a sharp decrease in the subject's activity, as does the timestamp in the second half of October 2016.
- During November 2016, all the detected change timestamps indicated a slow decrease in bathroom activity behavior. Whereas in December 2016, the detected change in timestamps indicated an increase in the subject's bathroom activity.
- Finally, the detected change in timestamps during January and February 2017 represent a decrease in the subject's bathroom activity.

For subject L, the monitoring period extended from April 2017 to February 2018, as presented in Supplementary Figure 5.

FIGURE 8
Bathroom activity time series for subject F, with detected change time stamps overlapped as vertical lines.
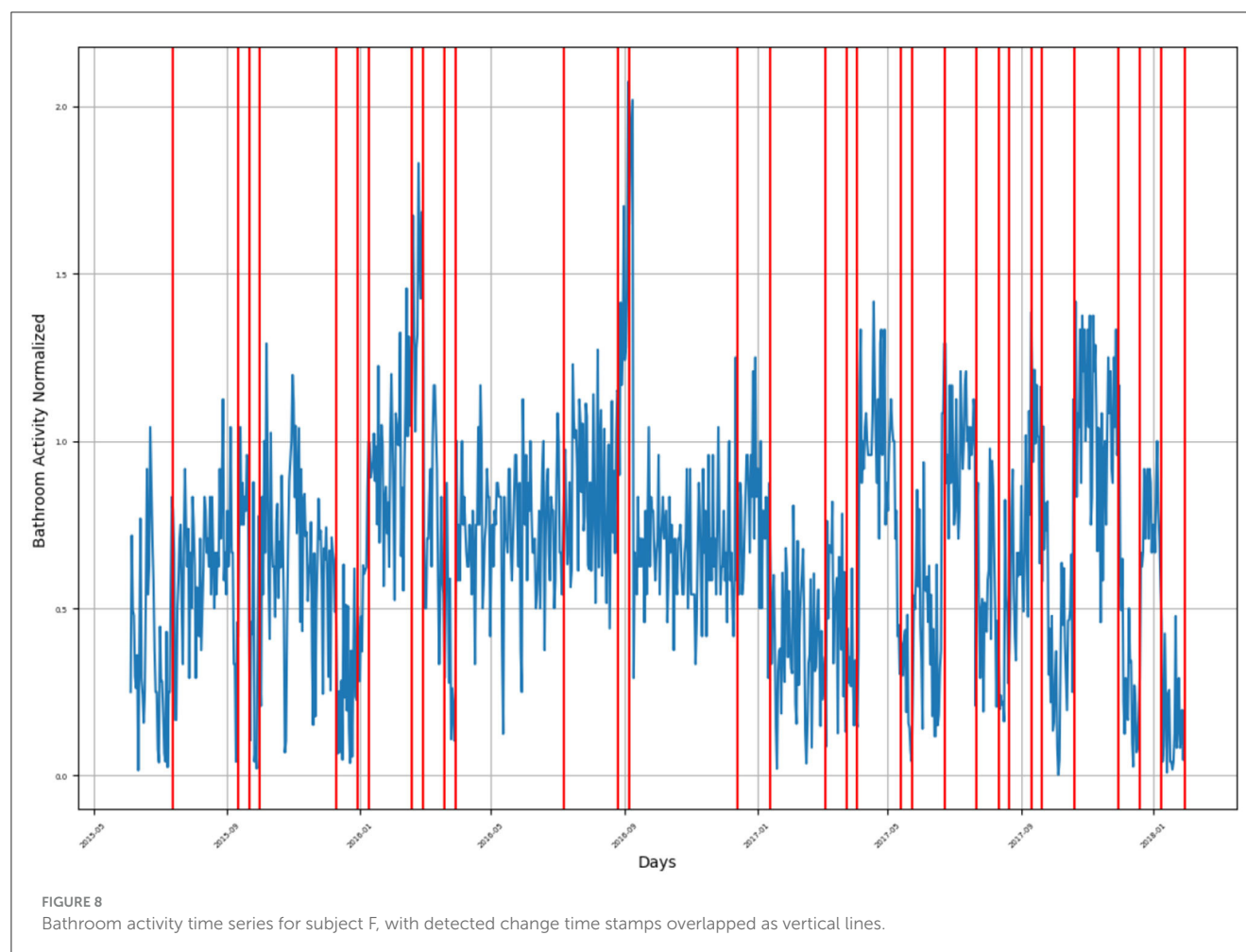
- The detected behavior change timestamps spanning from late April 2017 to the beginning of May 2017 indicate decreasing bathroom activity behavior, while behavior change timestamps in the second half of May 2017 indicate increased bathroom activity behavior.
- Furthermore, the single change timestamp in late June 2017 indicates an increase in bathroom activity behavior.
- During the period extending from July 2017 to mid-August, the general bathroom behavior of the subject was decreasing except for a few sharp spikes indicating a sudden increase in the behavior; the sharpest spike is at the end of July with a normalized value of 1.5 visits per hour.
- Another two decreasing behavior segments were found from late November 2017 to mid-December 2017 and from the beginning of January 2018 to mid-January 2018.

The detected behavior change timestamps along these two segments indicate a sharp and unexpected increase in the subject's bathroom activity behavior.

For subject M, the monitoring period extended from October 2016 to January 2018, as presented in Supplementary Figure 6. There are multiple groups of detected change timestamps, as follows:

- The first group extends from mid-October 2016 to November 2016, representing a positive inflection point in the subject's bathroom activity behavior, meaning that there has been a sudden increase followed by a sudden decrease in his activity behavior.
- During December 2016, there was a detected increase in the subject's bathroom behavior, while at the beginning of January 2017, there were two detected timestamps indicating a sudden decrease in the subject's bathroom behavior.
- At the beginning of March 2017, there was a detected decrease in the subject's behavior, while in April 2017, there were three detected change timestamps indicating an increase in the subject's behavior.
- From May 2017 to June 2017, there was a detectable decrease followed by an increase in the subject's bathroom behavior.
- In the first week of July 2017, there was a decrease in activity detected by two change timestamps.
- In late August 2017, another decrease in the subject's behavior was detected, followed by a mild decrease at the beginning of September 2017.
- Starting in October 2017, all the detected change timestamps indicate an increase in bathroom activity.

FIGURE 9
Bathroom activity time series for subject G, with detected change time stamps overlapped as vertical lines.
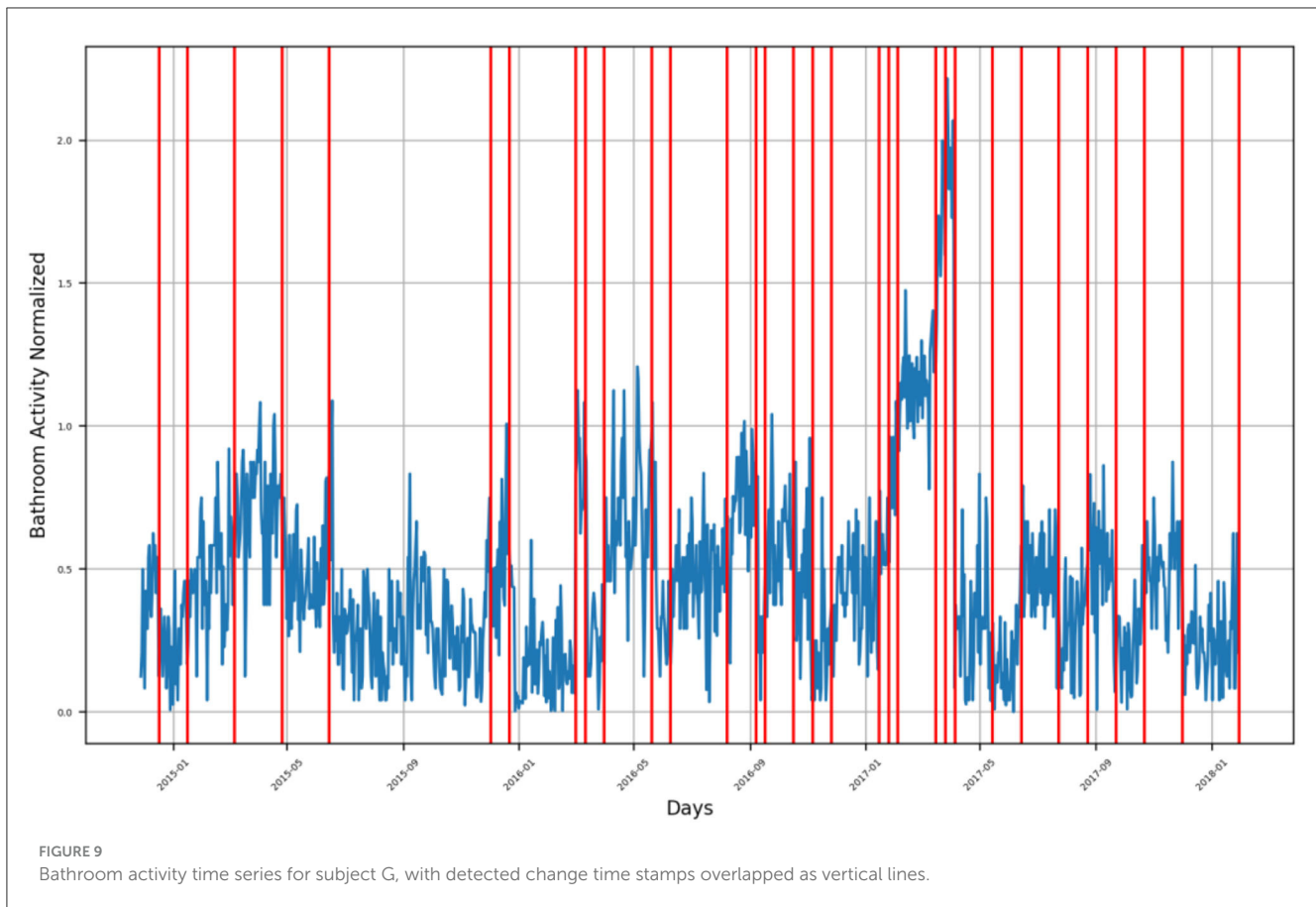
For subject N, the monitoring period extended from late October 2016 to January 2018, as presented in Supplementary Figure 7.
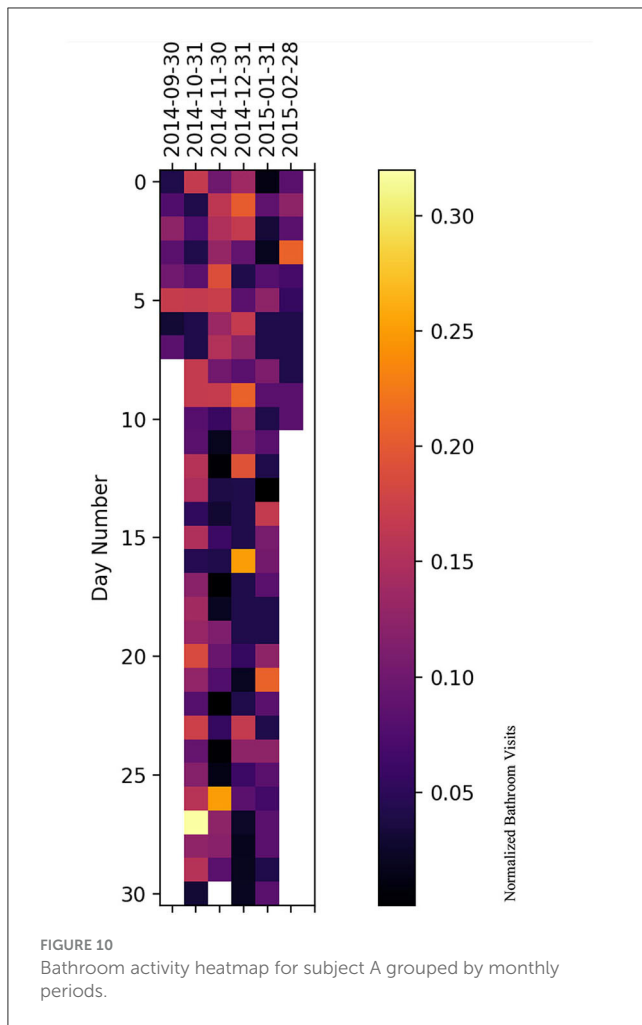
- The general bathroom activity behavior of the subject shows a slowly increasing pattern until July 2017, followed by a sudden decrease during July 2017, after which there was another slowly increasing behavior.
- The detected change timestamps in late October 2016 and at the beginning of November 2016 indicate decreasing bathroom behavior.
- In the beginning of December 2016, a sudden increase in activity was detected, followed by a sudden decrease in the subject's behavior.
- The detected change timestamps during the period extending from January 2017 to July 2017 indicate an increasing behavioral change for the subject.

For subject P, the monitoring period extended from late March 2017 to July 2017, as presented in Supplementary Figure 8. The general bathroom activity behavior of the subject shows a decreasing behavior at the beginning of the monitoring period, followed by increasing activity toward the end.

- First group: Two detected change timestamps indicate a decrease in the behavior, while the third one indicates an increase in the same behavior.
- In the first week of May 2017, there was a detected decrease in the subject's bathroom activity, while in the second half of May 2017, there was a detected increase in activity.
- At the end of the first week of June 2017 and on May 15, there were two detected change timestamps indicating an increase in the subject's activity behavior, whereas in the second half of May 2017, there was a detected timestamp that indicated a sudden increase in the subject's behavior.

For subject V, the monitoring period extended from October 2017 to February 2018, as presented in Supplementary Figure 9. There are four groups of detected behavior change timestamps along this period, as follows:

- The first group is found from late October 2017 until the beginning of November 2017 and consists of three detected timestamps, all indicating decreasing bathroom behavior for the subject.
- The second group consists of two detected timestamps, indicating a sudden increase in bathroom behavior after nearly zero-bathroom visits in the previous days, they were found in mid-November 2017 and late November 2017.

FIGURE 10
Bathroom activity heatmap for subject A grouped by monthly periods.

FIGURE 11
Bathroom activity heatmap for subject B grouped by monthly periods.

- The third group consists of four detected timestamps indicating both decreasing and increasing bathroom behavior. Whereas the first two timestamps in the third group indicate decreasing behavior, the last two indicate increasing behavior.
- The last group of detected timestamps consists of six timestamps. The first indicates the beginning of a sudden increase in activity behavior, and the remaining five indicate decreasing activity.

5.2. Heatmap representation

We have plotted a heatmap for each subject with the vertical axis as the number of days within a given month and the horizontal axis as the month itself to visualize the normalized bathroom activity for each subject individually to help decision-making by physicians or medical staff.

For subject A (Figure 10), it is clear that the subject had increased bathroom activity on 1st of November and the 11th of December.
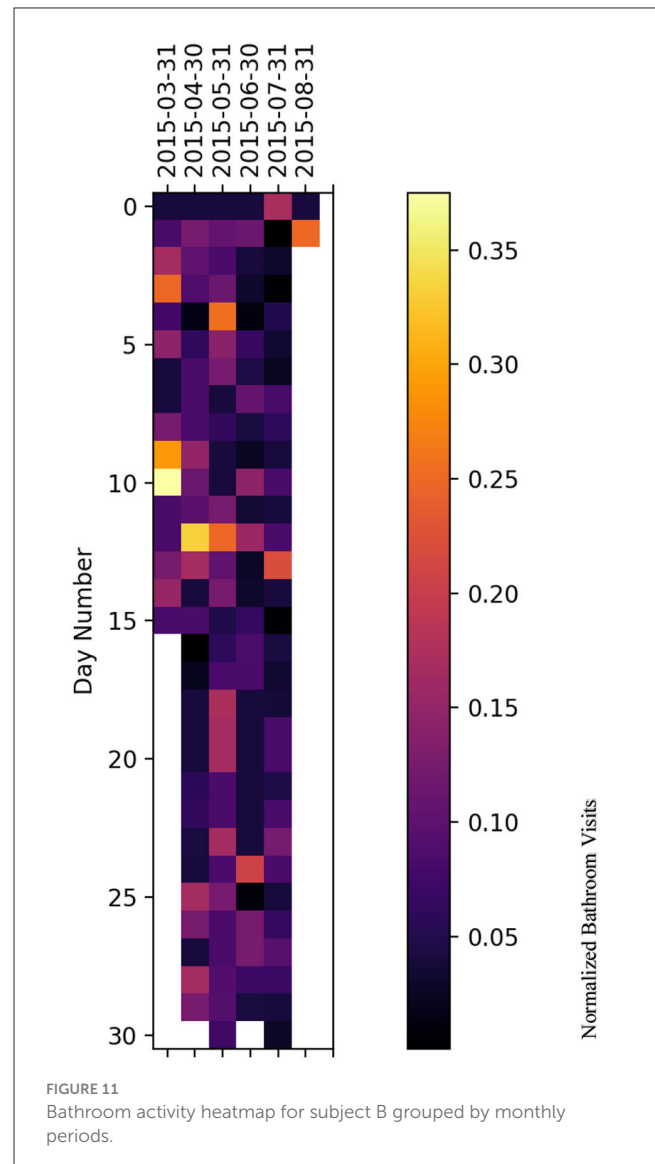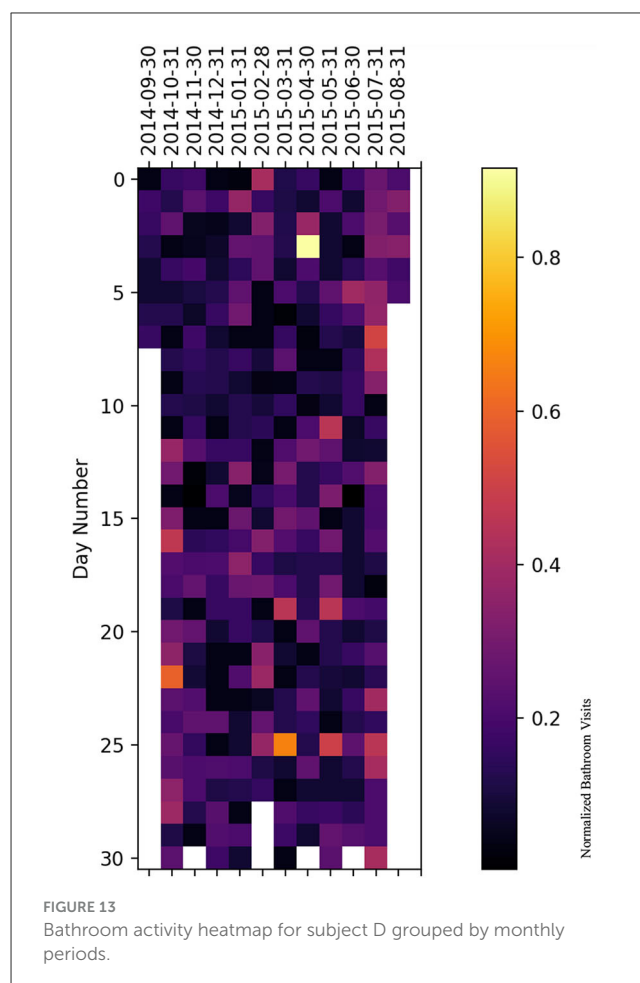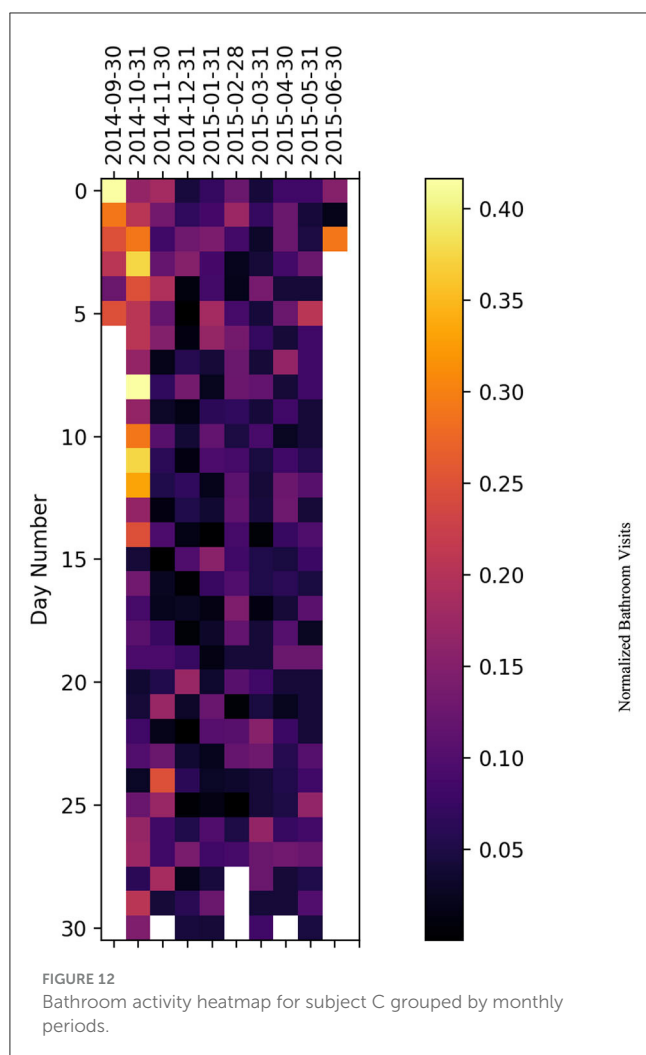
For subject B (Figure 11), the subject experienced increased bathroom activity on 8 March 2015 compared to the remaining monitoring days.

For subject C (Figure 12), the subject experienced an increased activity on November 18 and 29 November 2016. Furthermore, there was increased bathroom activity on 28 June 2017, 7 October 2017, 10, 19, and 26 November 2017, and 11 and 13 January 2018.

For subject D (Figure 13), the subject experienced increased bathroom activity on 12 March 2015 and 3 April 2015.

For subject E (Figure 14), the subject's behavior shows a decreasing bathroom activity behavior during the period extending from August 2015 to October 2015, and during the period extending from February 2016 to May 2016. The subject experienced increased bathroom behavior during the periods extending from October 2016 to January 2017, from April 2017 to July 2017, and in October 2017. Specifically, increased behaviors were found on 26 and 27 November 2016, 8 December 2016, 1 May 2017, and 3 June 2017.

Bathroom activity heatmap for subject C grouped by monthly periods.

Bathroom activity heatmap for subject D grouped by monthly periods.

For subject F (Figure 15), the subject experienced an increase in bathroom activity in the period extending from October 2016 to January 2017, specifically on 18 October 2016, on 19, 22, and 25 December 2016, and on 13 January 2017.

For subject G (Supplementary Figure 10), the subject experienced an increase in bathroom activity during March 2015, April 2015, March 2016, April 2016, and May 2016. The highest bathroom activity can be found on 2 March 2016, 9 and 19 April 2016, and 4, 5, and 21 May 2016, respectively.

For subject H (Supplementary Figure 11), the subject experienced an increased bathroom activity behavior during September 2014 and October 2014, where the specific days of such an increase were on September 1st 2014 and October 8th 2014. There was a significant decrease in the subject bathroom activity in January 2015, March 2015, April 2015, and May 2015 as well.

For subject I (Supplementary Figure 12), the subject's bathroom activity was in general high. Whereas the highest values of bathroom activity were found in April 2017, June 2017, October 2017 and November 2017.

For subject J (Supplementary Figure 13), the subject's bathroom activity behavior was generally low except for 9 April 2015

when the subject experienced a sudden increase in his bathroom activity behavior.

For subject K (Supplementary Figure 14), the subject, in general, was experiencing an increase in his bathroom activity behavior. However, there were a few days where the bathroom activity was higher, specifically on 15 and 29 November 2016 and on 19 and 22 December 2016.

For subject L (Supplementary Figure 15), the subject, in general, was experiencing an increase in his bathroom activity behavior, where the highest activity value was on 24 April 2017, 4 May 2017, and 14 January 2018.

For subject M (Supplementary Figure 16), the subject was experiencing low bathroom activity, in general, except for October 2016. Typically, the subject experiences the highest activity on 6–8 October 2016.

For subject N (Supplementary Figure 17), the subject was experiencing high bathroom activity in July 2017, particularly on 1, 2, 3, 16, and 19 July 2017.

For subject P (Supplementary Figure 18), the subject was experiencing high bathroom activity on 1 April 2017 and 10 June 2017.
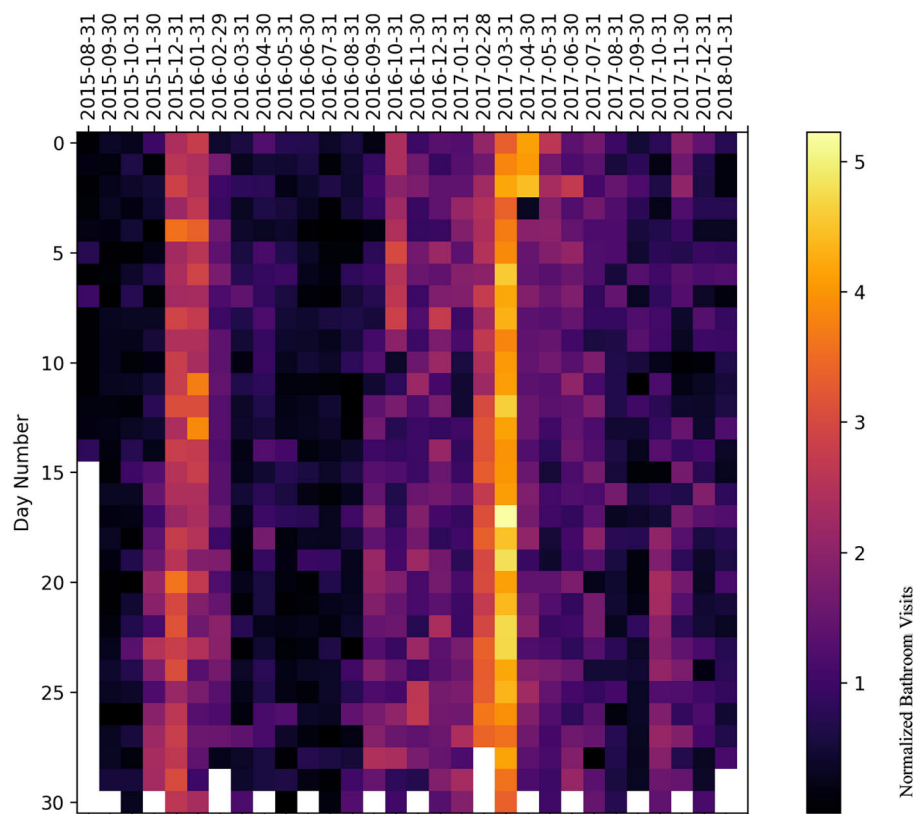
FIGURE 14
Bathroom activity heatmap for subject E grouped by monthly periods.

For subject V (Supplementary Figure 19), the general bathroom activity behavior of the subject was low except for 3 January 2018 where the subject had the highest bathroom activity value.

5.3. Insight

We implemented our system to help collaborating medical staff (doctors, caregivers, and nursing) better follow the subjects (e.g., to notify the medical staff of possible excretory function disorders experienced by the subject under investigation). To this end, we have compared our detection results with those obtained by medical staff.

According to medical staff reports, two subjects had excretory function disorders, subject I was reported to have a UTI, and subject H was reported to have IBS-related symptoms such as vomiting, diarrhea, and spending longer in the bathroom.

- For subject F, three consecutive increases affect the daily evolution of toilet entries. Subject F entered more frequently the toilet on 2015-09, 2015-10-10, 2015-10-20, 2015-10, 2016-03, 2017-04, 2017-06, 2017-10, and 2017-11. Collaborating medical staff confirmed urinary infection symptoms starting

from 2015-10. They observed frequent toilet entries, vomiting, and diarrhea until 2016-04.

  ○ Our system detected increased toilet visits, suggesting urinary infection events a few weeks before they were observed by the medical staff. The change detection results obtained by our approach conformed with those obtained by the medical staff, which means we were able to report bathroom activity behavior change that helped medical staff intervene early to solve the situation.
  ○ In addition, the normalized bathroom activity value that complied with the medical staff report was equivalent to 1.2 bathroom visits, meaning that it sums up to approximately 28 bathroom visits per day.

- For subject H, we found one significant decrease that affected the daily evolution of toilet entries; this decrease occurred on 2015-01-01. The nursing home team observed an increase in mobility impairments for subject H in 2015-01-15. By this time, subject H was no longer able to go independently to the toilet, as fecal elimination was observed both on the bed and all over the room.
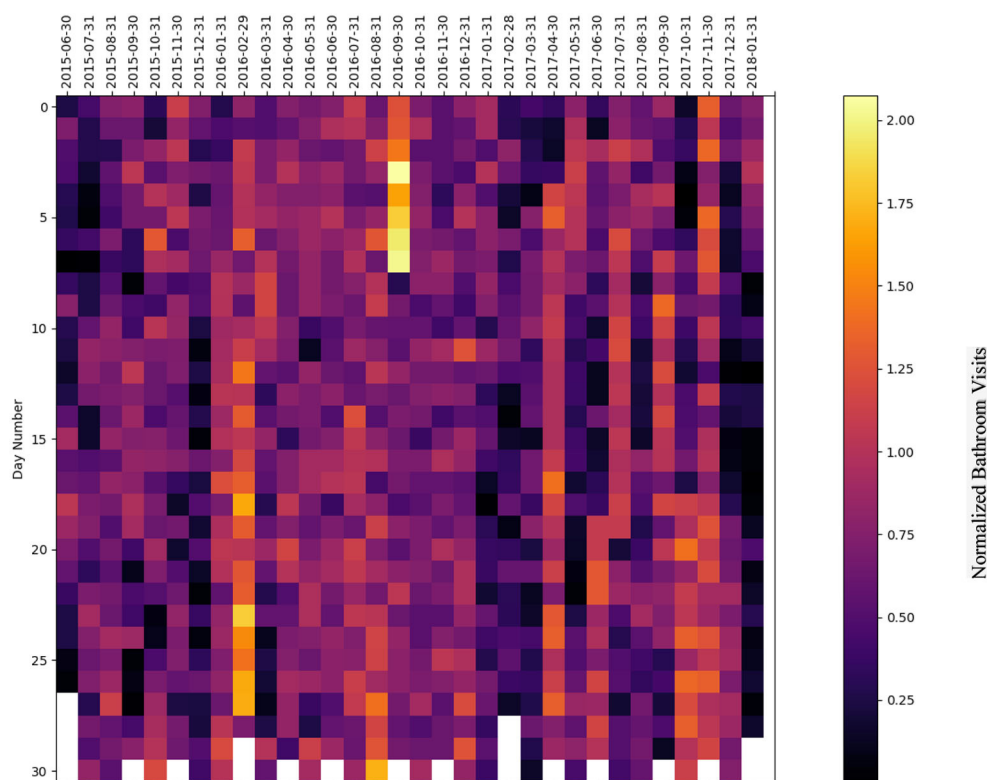
FIGURE 15
Bathroom activity heatmap for subject F grouped by monthly periods.

○ The medical staff report matched our detection results as to where we were able to report such degradation of bathroom activity behavior.

As for the other subjects, there were no reported issues/disorders by the medical staff. However, our analysis confirmed changes for all subjects. These changes were more notable for subject J on 2015-04-09, subject G in late April 2015, in March, April, and May 2016, subject F starting from October 2016 to January 2017, subject A on 1 November 2014 and 11 December 2014, subject B on 8 March 2015, subject C from October 2016 to January 2018, subject D on 3 April 2015, subject E starting from 25 November 2016 to October 2017, subject K on 15 November 2016 and 19 and 22 December 2016, subject L on 24 April 2017, subject M on October 2016, subject N on July 2017, subject P on 1 April 2017, and subject V on 4 January 2018.

We claim that these detected changes were due to UTI as our proposed algorithm counts the number of bathroom visits per day, or, in other words, accounts for the bathroom visit frequency, which is related to UTI. These changes may be related to situations that can result in more serious problems in future, which is why medical doctors need to be made aware of these behavior changes as soon as they are detected.

6. Conclusion

The Internet of Things (IoT) and artificial intelligence (AI)-based monitoring technology provide new objective information on daily living activities that complete classical medical observations. In this study, we proposed an attempt to effectively translate medical staff needs by deploying unobtrusive IoT monitoring technologies (e.g., environmental sensors and sensor-enhanced devices) for early detection of possible changes in health status. We focused on excretory functional disorders in older adults associated with urinary tract infections (UTIs) and irritable bowel syndrome (IBS).

Our IoT and AI-based approach consists of two parts: the first part is to calculate the bathroom visit frequency per day from acquired raw motion sensor data, and the second part detects the activity change based on a window-based calculation of the Pruned Exact Linear Time (PELT). With our approach, we were able to detect bathroom activity disorders by monitoring the bathroom activity of subjects on a daily basis across extended periods of time. In addition, we showed that we could help medical staff follow the health status of two subjects (i.e., H and I) based on our bathroom activity change alerting features to better diagnose and treat possible disorders.

In addition, we were able to establish a primary threshold value for bathroom activity. Specifically, subjects having approximately

1.2 normalized bathroom visits per day should be assumed to experience UTI, as confirmed by medical staff reports.

We have also detected changes that we claim could be associated with UTI but that were not noticed by caregivers. These behavior changes may be related to situations that can result in more serious problems for older adults in future. That is why medical doctors need to be aware of these changes as soon as they are detected. So, our system can alert medical staff in response to these unusual situations.

Our implemented algorithm accounts for the difference between the frequency of bathroom visits in the current time window and the past time window. For better identification of IBS, we are working on another algorithm that accounts for the time spent in the bathroom. We have tested that algorithm in the context of detecting different daily indoor activities using a thermal sensor array (TSA) system (46), and we expect to get promising results for both IBS and UTI.

In this study, we have highlighted how IoT and AI technologies can advance medical evaluations and upgrade medical assessments by offering novel and objective insights into everyday activities, where the use of sensor observations assists medical professionals in identifying situations that require more in-depth examination, supporting their medical assessments, and detecting patterns of decline that may not be obvious during standard office appointments.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: European project. Requests to access these datasets should be directed to HA, hamdi.aloulou@gmail.com.

Ethics statement

The studies involving human participants were reviewed and approved by Comités de Protection des Personnes (CPP) Ile-de-France VI Pitié-Salpêtrière Hospital Group. The patients/participants provided their written informed consent to participate in this study.

Author contributions

BA involved in medical concept proposal, conceptualization, data collection, funding acquisition, methodology, review, editing, writing, and supervision. HM involved in medical background formulation, investigation, data curation, methodology, data analysis conceptualization, formal analysis, visualization, and writing and editing. HA involved in medical concept proposal, conceptualization, data collection, data curation, investigation, methodology, writing, reviewing, and participate in writing and editing. MM involved in data acquisition funding, data collection, data curation, and reviewing. FB involved in data curation, methodology, formal analysis, visualization, review, editing, and supervision.

Acknowledgments

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.2023.1161943/full#supplementary-material

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Occupational characteristics and disability-free survival after retirement age: an exploratory analysis from the ASPREE study

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Background: Certain occupational characteristics have been linked with poor health and reduced longevity. However, the association between occupational characteristics and survival free of disability in a post-retirement age group has not been investigated.

Methods: We investigated outcomes in 12,215 healthy older Australian adults in the Aspirin in Reducing Events in the Elderly (ASPREE) and ASPREE Longitudinal Study of Older Persons (ALSOP) sub-study. The ISCO-88 major occupational groups, settings, and activity levels were assigned based on free-text job descriptions. The Finnish Job Exposure Matrix was used to assign occupational characteristics to the three longest-held jobs. The primary endpoint, disability-free survival, was defined as a composite measure of death, dementia, or persistent physical disability. The endpoint of all-cause mortality was analyzed separately. Because of multiple exploratory analyses, only those associations with a two-sided value of p less than 0.005 were considered statistically significant. Cox proportional hazard models were used to calculate adjusted hazard ratios.

Results: Having worked in an 'elementary' occupation was associated with a reduction in disability-free survival. A specific impact on disability-free survival was observed among those whose work had involved high accident risk and adverse social climate. No significant relationship was identified with those previously exposed to sedentary work, vigorous physical activity, work primarily outdoors, or a range of other occupational characteristics. All-cause mortality was not increased among any of the occupational groups.

Conclusion: This exploratory study found a reduction in disability-free survival among people who worked in 'elementary' occupations, with specific risks associated with occupations involving high accident risks and adverse social climate.

Introduction

Differences between occupations and their cumulative effects during working life are thought to contribute to variations in the incidence and mortality associated with several chronic diseases of aging (1). The Whitehall study of British civil servants was the first to demonstrate marked differences between mortality among individuals from different positions in the social hierarchy of occupations (2, 3). Higher mortality from cardiovascular diseases and a range of other causes of death occurred among those with the lowest-status occupations compared to those with higher managerial jobs although the extent to which this could be attributed to occupational, environmental, genetic, individual socio-economic, or lifestyle factors was unclear. Since then, many other studies have reported a relationship between various occupational characteristics and exposures and increased ill health and mortality later in life (4–6).

Most studies of the impact of occupations on future health have focused on mortality or on the incidence of specific diseases (5, 7–9). However, with many societies experiencing rapid aging of their populations, another social and economic imperative is to maintain an individual's independence as long as possible, thereby reducing the need for institutional care. Disability-free survival, defined as survival free of severe physical disability or dementia has been proposed as a surrogate measure of independence, of particular relevance to studies of older people (10). To date, there is little information available about the impact of occupational factors on this important measure of population health.

The Aspirin in Reducing Events in the Elderly (ASPREE) study was a large, randomized clinical trial of low-dose aspirin and placebo in which disability-free survival was the primary outcome. Australian participants were healthy adults aged ≥70 years when recruited in 2010–2014 (11). Within a sub-study, an abbreviated occupational history, which included jobs held between approximately 1950 and 2009, was obtained. This analysis aims to determine the relationship between occupational characteristics and disability-free survival and mortality in healthy older adults. Understanding this relationship may help improve health outcomes and quality of life for older adults after retirement and inform public health policies and intervention strategies to promote healthy aging.

Methods

Study design and population

The detailed methodology of the ASPREE trial including its recruitment and primary endpoints has been reported (11). Participants enrolled were aged ≥70 years and were required to fulfill the eligibility criteria, which included the absence of previously diagnosed cardiovascular disease, dementia, physical disability, or any other illnesses likely to limit survival to less than 5 years. Shortly after enrolment, Australian ASPREE participants were invited to enroll in the ASPREE Longitudinal Study of Older Persons (ALSOP) sub-study which consisted of baseline and follow-up questionnaires (12). The information requested at baseline included information about occupational, environmental, lifestyle, behavioral, social, and economic factors. Ethical approval was obtained from the Monash University Ethics Committee

(project numbers CF11/1100 and CF11/1935), and written informed consent was obtained from all participants.

Occupational data coding and classification

A total of 12,498 participants provided information on up to three jobs that they had held for the longest duration during their working life. Information requested included the job title, employer industry, task descriptions, and years worked (12). These occupational histories were coded according to the four-digit International Standard of Occupations (ISCO-88) classification (13).

In the initial analysis, participants were categorized into nine main groups based only on the first digit of ISCO-88 codes. This initial digit indicates the primary occupational group for each participant among all potential occupations in the population. These occupational groups are (1) legislators, senior officials, and managers, (2) professionals, (3) technicians and associate professionals, (4) clerks, (5) service workers and shop and market sales workers, (6) skilled agricultural and fishery workers, (7) craft and related trades workers, (8) plant and machine operators and assemblers, and (9) elementary occupations (further details in Supplementary Table S1).

The ISCO-88 codes were converted to Finnish O-codes, and the Finnish Job Exposure Matrix (FINJEM) (up to 2007–09) was used to define occupational characteristics (14), as previously applied in the Australian population (15). For each job code, FINJEM indicates the likelihood that the job did or did not entail a particular exposure or characteristic. For these analyses, FINJEM was used to determine psychological, physical, and ergonomic exposures (definitions in Supplementary Table S2) (16). To simplify the analyses FINJEM exposures were categorized into dichotomous variables, ever-exposed vs. never-exposed (more detail in Supplementary Methods).

Based on job titles, the likely occupational setting was designated as indoors, outdoors, or combined indoor/outdoor. Additionally, the likely physical demands of the job were classified as mostly sitting or standing, involving moderate physical activity or vigorous physical activity. This classification was undertaken by a team experienced in occupational coding and verified by an expert occupational hygienist (GB).

Endpoints

Participants were recruited from March 2010 to December 2014 and followed up for a mean of 6.3 (SD 1.8) years during the ASPREE trial and ASPREE-XT (extension). The primary endpoint, disability-free survival (DFS), was defined as the time to the first occurrence of death, dementia, or persistent physical disability (17). Physical disability was assessed for 6 months and was defined as a persistent loss of one of the six Katz Activities of Daily Living or admission to nursing home care because of physical disability. The presence of dementia was determined using the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders by a panel of expert adjudicators (11, 17). Death was a secondary endpoint, identified during the trial period from health records, death notification from close contacts, and by linkage to the Australian National Death Index

Statistical analyses

Cox proportional hazards regression models with time-to-event analysis were used to compare the occupational setting, FINJEM exposures, and activity level with health outcomes. Hazard ratios (HRs) and 95% confidence intervals (CIs) were calculated, and participants were censored at the time of the event of interest. The proportional hazards assumption was checked using Schoenfeld residuals and found to be appropriate. A competing risk model was used with censoring at the time of death to develop the cumulative incidence plots.

The model was adjusted for age, sex, and smoking. Some of our analyses were further stratified by sex. Specific sensitivity analyses were carried out to account for education as additional confounding variables. With additional analyses, the hazard ratios were further adjusted for confounders such as alcohol use, body mass index, and hypertension. Cell sizes of less than five cases were not reported in the analyses, and to account for the multiple analyses, a two-sided value of p of <0.005 was used as the cutoff for statistical significance. All the analyses were conducted using Stata version 18 (StataCorp, College Station, TX).

Results

A total of 12,215 participants who provided work histories were included in this analysis (Figure 1). Table 1 shows their baseline characteristics. The predominant occupations for men were craft and trade workers ($n = 1,349$), followed by professionals ($n = 1,072$) and machine operators ($n = 791$). Among women, the predominant ISCO-88 occupations were clerks ($n = 2,197$), professionals ($n = 1,429$), and service workers or retail salespersons ($n = 1,140$; Figure 2).

More than half of the men worked in 'blue-collar' occupations (56%), and men were more likely than women to have a job involving vigorous physical activity (39% vs. 6%). Women predominantly worked indoors (92%), and just over half had roles that involved sitting and/or standing without physical activity (51%). Among men, 3% were current and 54% were former smokers, while among women, 2% were current and 31% were former smokers.

Disability-free survival

Table 2 compares the primary outcome of disability-free survival among the ISCO-88 initial-digit occupational groups. A hazard ratio greater than 1.0 indicates a reduction in disability-free survival compared to all other participants. Using the statistical significance level of 0.005, a reduction in disability-free survival was observed for men in 'elementary' occupations (HR 1.29, 95% CI 1.07–1.56). This relationship remained after adjusting for additional confounders in the model, as shown in Supplementary Table S4.

A reduction in disability-free survival was also found among participants reporting jobs in occupational groupings defined by FINJEM as having a high accident risk (HR 1.35, 95% CI 1.15–1.61) or associated with an 'adverse social climate' at work (refers to communication, information flow, and cooperation; full definitions in Supplementary Table S2) (HR 1.86, 95% CI 1.11–1.97) (Table 3). There was no evidence of a reduction in disability-free survival among those whose past occupational history involved sedentary work, vigorous physical activity, work primarily outdoors, or a range of other occupational characteristics (Table 4).
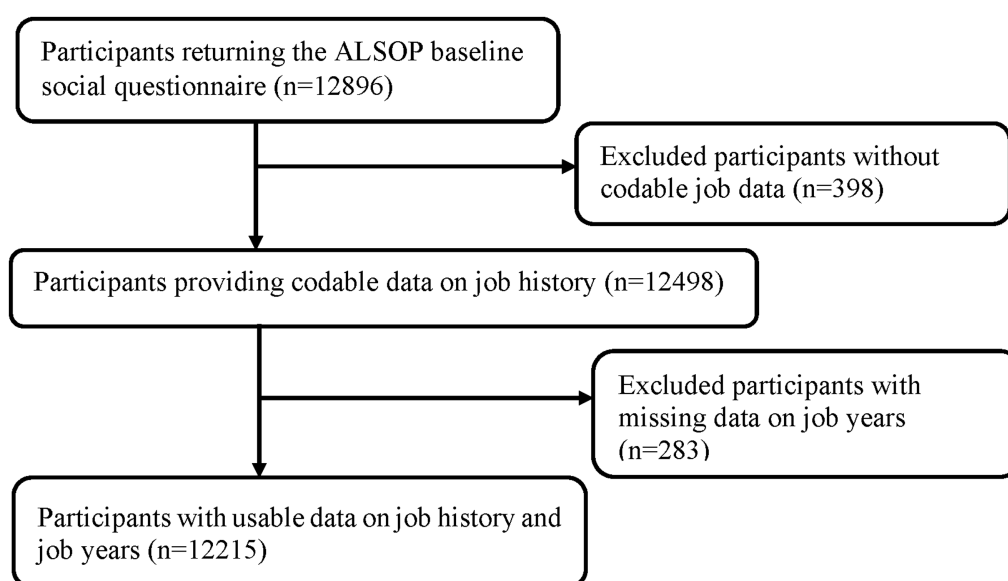

FIGURE 1
Flowchart illustrating the identification of the study population.

TABLE 1 Baseline characteristics of ALSOP cohort stratified by occupational activity.

Study characteristics	Men, 5,569 (45.6%)	Women, 6,646 (54.4%)
Age, year (mean, SD)	75.07 (4.32)	75.21 (4.26)
Education, (%)		
<12 years education	2,498 (44.9)	3,333 (50.2)
≥12 years education	3,071 (55.1)	3,313 (49.9)
Body mass index, kg/m², mean (SD)	27.85 (3.76)	27.98 (5.02)
Waist circumference, cm, mean (SD)	101.74 (10.48)	92.87 (12.53)
Smoking history n (column %)		
Never	2,389 (42.9)	4,421 (66.5)
Current	192 (3.5)	149 (2.2)
Former	2,988 (53.7)	2076 (31.2)
Alcohol users, n (%)		
Never	469 (8.4)	1,403 (21.1)
Current	4,796 (86.1)	4,979 (74.9)
Former	304 (5.5)	264 (4.0)
Diabetes, (%)	644 (11.6)	514 (7.7)
Hypertension, (%)	4,187 (75.2)	4,871 (73.3)
Paid employment, (%)		
No paid employment	46 (0.8)	34 (0.5)
Paid employment	5,469 (99.2)	6,570 (99.5)
Employment status, (%)		
Full-time	5,452 (99.3)	5,166 (79.9)
Part-time	29 (0.5)	1,180 (18.3)
Casual	12 (0.2)	116 (1.8)
Type of jobs, (%)		
Blue collar	3,132 (56.2)	2,442 (36.7)
White collar	2,437 (43.8)	4,204 (63.3)
ISCO-88 major groups*		
Legislators, senior officials, managers	287 (5.2)	54 (0.8)
Professionals	1,072 (19.3)	1,429 (21.5)
Technicians and associate professionals	638 (11.5)	480 (7.2)
Clerks	395 (7.1)	2,197 (33.1)
Service workers, shop, and sales workers	285 (5.1)	1,140 (17.2)
Skilled agriculture and fishery workers	353 (6.3)	163 (2.5)
Craft and related trade workers	1,349 (24.2)	253 (3.8)
Plant and machine operators and assemblers	791 (14.2)	375 (5.6)
Elementary occupations	243 (4.4)	404 (6.1)
Occupational settings		
Indoor only	3,045 (54.7)	6,123 (92.1)
Outdoor only	1,610 (28.9)	365 (5.5)
Indoor and outdoor	914 (16.4)	158 (2.4)
Occupational activities		
Moderate physical activity	1,000 (18.0)	2,822 (42.5)
Sitting/standing jobs	2,403 (43.2)	3,423 (51.5)
Vigorous physical activity	2,166 (38.9)	401 (6.03)

*People are classified in any of their three jobs reported.

All-cause mortality

All-cause mortality was not significantly increased among any major occupational groups (Table 2) nor were specific risks identified as reaching the predefined level of statistical significance ($p < 0.005$; Table 3) or activity levels in the workplace or indoor/outdoor work locations (Table 4).

Discussion

This large prospective survivor's cohort study is the first to examine the association between occupational characteristics and disability-free survival in an older adult population in the post-retirement period. Disability-free survival is a surrogate measure of independent living which is particularly relevant in an aging population. The principal finding was a reduction in disability-free survival associated with the least skilled or 'elementary' occupations. These include cleaners, garbage collectors, and laborers in agriculture, fisheries, mining, construction, mining, and manufacturing.

Among the specific job characteristics, those with the major adverse influence on disability-free survival were working in an adverse social environment and work that involved a high accident risk. All of these are likely to be characteristics of 'elementary' occupations and to provide a potential explanation for the lower likelihood of healthy survival among these workers.

Of the ASPREE participants who died, 45% developed either dementia or persistent physical disability prior to death [17]. However, all-cause mortality was not substantially different among the four-digit ISCO-88 occupation groups, including elementary occupations. This indicates that the significant reduction in disability-free survival among the elementary occupational groups is likely to have resulted from an increase in physical disability or dementia related to occupational history [18].

The relatively similar mortality among participants, including those working in elementary occupational groups contrasts with previous reports including the United States National Longitudinal Mortality Study [1] and the Whitehall study of United Kingdom civil servants [2]. A report using Korean insurance claim data also found higher mortality among lower occupational categories and a study from Japan found a high mortality in elementary occupations with most of the mortality due to cancer [19, 20]. As all participants in ASPREE were recruited as healthy, the analyses of mortality may be biased due to the selective exclusion of those most likely to die prematurely from occupational factors. Alternatively, it might reflect a declining social gradient within the Australian workforce or the impact of occupational health and safety standards introduced progressively over the working life of the ASPREE participants.

The results of this study add to a growing literature on the effect of occupational characteristics and exposures on other aspects of health in later life. These include a recent Global Burden of Disease study, which reported an increase in disability-adjusted life years attributable to several occupational factors [21]. Several population-based cohorts have also reported links between physically demanding jobs, shift work, ergonomic and psychological stress factors, and all-cause mortality [4, 5, 7–9]. The results of recent community-based cohort studies investigating the relationship between occupational factors and mortality are summarized in Supplementary Table S5. In particular, the association between heavy physical work and mortality, particularly in men has also been documented in other occupational studies [4, 6, 22].
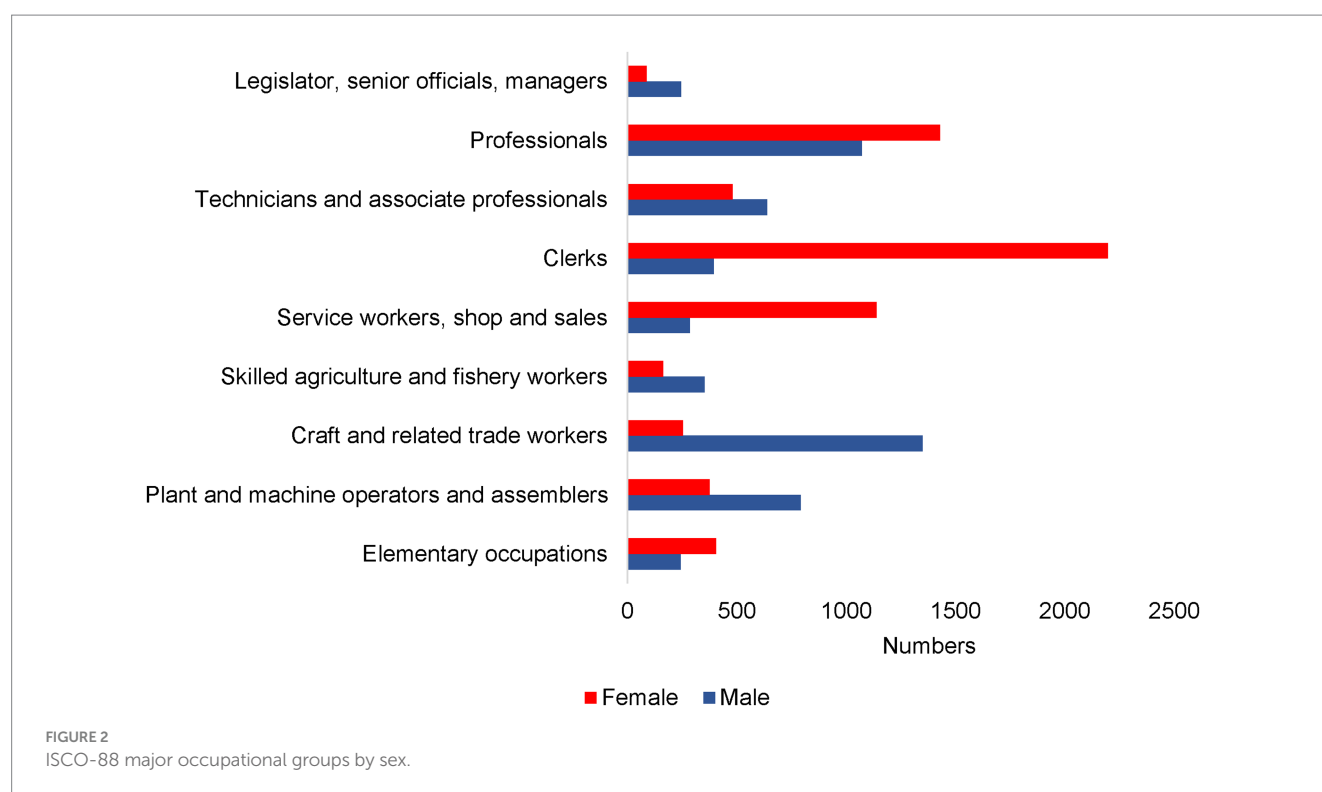
FIGURE 2
ISCO-88 major occupational groups by sex.

TABLE 2 Association between disability-free survival and mortality in Australian healthy older adults with ISCO-88 major occupational groups.

ISCO-88 single-digit occupational groups†		Reduction in disability-free survival (DFS)			All-cause mortality		
		n!	HR (95% CI)	Value of *p**	*n*!	HR (95% CI)	Value of *p*
Group 1	*Legislators, senior officials, and managers*	45	1.07 (0.82–1.42)	0.598	33	1.15 (0.86–1.56)	0.346
Group 2	*Professionals*	311	0.83 (0.75–1.02)	0.096	191	1.00 (0.87–1.15)	0.996
Group 3	*Technicians and associate professionals*	162	1.04 (0.87–1.24)	0.667	100	1.01 (0.8–1.29)	0.877
Group 4	*Clerks*	311	0.96 (0.84–1.09)	0.559	182	0.84 (0.70–1.00)	0.053
Group 5	*Service workers, shop and sales workers*	184	1.01 (0.87–1.19)	0.814	114	0.99 (0.80–1.23)	0.985
Group 6	*Skilled agriculture and fishery workers*	61	1.26 (1.04–1.55)	0.022	40	1.19 (0.88–1.62)	0.257
Group 7	*Craft and related trade workers*	248	0.96 (0.84–1.11)	0.626	156	0.87 (0.73–1.03)	0.112
Group 8	*Plant and machine operators and assemblers*	171	1.15 (0.98–1.35)	0.081	109	1.26 (1.03–1.56)	0.025
Group 9	*Elementary occupations*	109	**1.29 (1.07–1.56)**	**0.005**	75	1.12 (1.07–1.39)	0.029
	Rate per 1,000 person-year		18.1			12.03	

The HR were adjusted for age, sex, and smoking. !Number of exposed individuals with an outcome of DFS or mortality. †Participants not in the specific occupational category were used as a reference group. Individuals ever employed in one of these occupational groups were included (therefore, a single individual might have been included in more than one group). A value of *p* < 0.005 was considered statistically significant and presented as bold in the table.

Overall, this study suggests that some specific occupational characteristics may lead to adverse outcomes later in post-retirement age. Despite this, it is impossible to exclude the likelihood that the reduction in healthy survival reflects socioeconomic disadvantage, poor health behaviors, and the likelihood that individuals with pre-existing physical or cognitive limitations select elementary occupations. Smoking, in particular, was more common among individuals working in low-skilled labor-intensive occupations, but the influence of cigarette smoking was at least partially controlled in our analysis.

The public health significance of these findings arises from the substantial proportion of the workforce who undertake elementary and laboring occupations for a significant part of their working lives. Based on

this analysis, these individuals may generate substantial additional costs for supportive care and social services in their older years. This emphasizes the need to determine more precisely whether job characteristics or other (e.g., lifestyle) characteristics lead to adverse health outcomes. Meanwhile, attention is needed to mitigate the potentially harmful effects of the negative attributes identified in this study.

This study has several strengths. For the first time, we investigated the association between occupational factors and disability-free survival and all-cause mortality in a sample from a healthy general population aged 70 years and older, in both men and women. The ASPREE study was subject to rigorous quality control, and all endpoints were actively screened, and verified by access to clinical

TABLE 3 Association between disability-free survival and mortality in Australian healthy older adults and occupational factors.

Occupational factors from FINJEM*	Reduction in disability-free survival			All-cause mortality		
	n†	HR (95% CI)	Value of p‡	n†	HR (95% CI)	Value of p‡
Psychological and organizational stress factors						
Challenge at work	18	0.50 (0.49–1.1)	0.285	7	0.54 (0.32–0.89)	0.01
Control possibilities at work	17	1.19 (0.83–1.7)	0.332	8	1.41 (0.71–2.77)	0.325
Perceived risks at work	17	1.22 (0.85–1.74)	0.299	9	1.25 (0.89–1.73)	0.185
Adverse social climate at work	12	1.86 (1.11–1.97)	0.002	11	1.49 (0.8–2.78)	0.21
Social demand at work	24	0.67 (0.47–0.96)	0.028	17	0.77 (0.60–0.98)	0.039
Supervisor support	16	0.77 (0.35–1.73)	0.532	8	0.99 (0.99–1.01)	0.352
Working time arrangement	18	0.67 (0.36–1.27)	0.219	9	0.92 (0.50–1.72)	0.808
Physical factors						
Ionizing radiation	4	1.88 (0.54–6.52)	0.319	4	2.52 (1.15–5.54)	0.020
Low-frequency magnetic fields	35	0.82 (0.54–1.23)	0.349	20	0.97 (0.59–1.59)	0.92
Noise	11	0.65 (0.44–0.99)	0.044	8	0.75 (0.39–1.43)	0.384
Ultraviolet radiation	31	0.95 (0.68–1.33)	0.758	17	0.92 (0.51–1.65)	0.776
Ergonomic factors						
High accident risk	120	1.35 (1.15–1.61)	<0.001	72	1.29 (1.08–1.49)	0.028
Inconvenient and difficult work postures	65	1.14 (0.89–1.45)	0.303	40	1.2 (1.07–1.4)	0.033
Manual handling	69	0.94 (0.77–1.15)	0.569	44	0.96 (0.76–1.22)	0.692
Perceived physical workload	65	0.94 (0.72–1.23)	0.654	39	0.86 (0.60–1.23)	0.418
Repetitive work movements	86	1.04 (0.84–1.28)	0.711	54	0.97 (0.72–1.31)	0.864
Sedentary work	10	1.25 (0.79–1.95)	0.331	11	1.23 (0.64–2.39)	0.536
Work with video display units	96	0.92 (0.75–1.15)	0.481	59	0.99 (0.78–1.26)	0.923

The hazard ratios were adjusted for age, sex, and smoking. †Number of participants with outcome and exposure. ‡A value of $p < 0.005$ was considered statistically significant and presented as bold in the table. *Definitions of occupational factors are included in the online Supplementary material.

TABLE 4 Association between disability-free survival and mortality in Australian healthy older adults with occupational setting and activity.

Occupational factors	Reduction in disability-free survival			All-cause mortality		
	n†	HR (95% CI)	Value of p*	n†	HR (95% CI)	Value of p*
Occupational settings						
Men						
Indoor only	464	Ref.		321	Ref.	
Outdoor only	248	1.21 (1.03–1.42)	0.017	171	1.02 (0.83–1.24)	0.793
Indoor and outdoor	137	1.01 (0.84–1.22)	0.91	97	1.02 (0.82–1.25)	0.882
Women						
Indoor only	732	Ref.		392	Ref.	
Outdoor only	39	1.46 (1.08–1.95)	0.012	22	1.40 (1.07–2.02)	0.041
Indoor and outdoor	21	0.67 (0.46–1.02)	0.059	13	0.82 (0.51–1.31)	0.115
Occupational activities						
Men						
Moderate physical activity	166	Ref.		119	Ref.	
Sitting/standing jobs	355	1.01 (0.87–1.16)	0.945	246	0.93 (0.73–1.18)	0.486
Vigorous physical activity	328	1.38 (1.09–1.44)	0.027	224	1.17 (0.96–1.44)	0.11
Women						
Moderate physical activity	359	Ref.		194	Ref.	
Sitting/standing jobs	387	1.01 (0.88–1.18)	0.811	210	0.91 (0.75–1.12)	0.378
Vigorous physical activity	46	1.12 (0.82–1.53)	0.473	23	1.29 (1.07–1.85)	0.039

The hazard ratios were adjusted for age and smoking. †Number participants with exposure and endpoints. *A value of $p < 0.005$ was considered statistically significant.

records, which allowed the identification of the proximal cause of death. We used FINJEM, which is designed for a general population-based study. The advantage of using JEM is that it excludes recall bias and minimizes differential misclassification. In addition, the FINJEM period allows us to consider exposure at the time of employment. Finally, we adjusted for smoking as a confounder in the final models and performed a range of sensitivity analyzes to overcome the effect of residual confounding in the analyses.

Limitations included the restriction of occupational histories to the three longest-held jobs rather than a complete job history. Increased risks among women are likely to be underestimated as a result of their shorter duration in the workforce in this cohort (23). Alcohol intake is a potential confounder but was not included in the models because of the likely low validity of self-reports, its close correlation with smoking, and the very small number of individuals in this population declaring a high alcohol intake. FINJEM classifies exposures based on job titles only and cannot account for variations in characteristics of jobs with the same title. Being based on Finnish occupational data, the use of FINJEM to assess occupational factors, such as adverse social climate, might not necessarily reflect Australian working conditions.

It should be noted that the current investigation considered all Australian ASPREE participants, irrespective of their treatment allocation to either low-dose aspirin or placebo in the main intervention trial. The decision to include all Australian participants was made in light of the widespread use of aspirin in the population, with 7.2% of Australian participants being regular users prior to the trial (24). Nevertheless, sensitivity analyses demonstrated that adjusting for additional confounding factors had no impact on the overall effect estimates, as presented in Supplementary Table S4. A second analysis in which the results were presented adjusted for aspirin use in the trial allocation (data not shown) also found no discernible differences between the two groups.

In summary, this study reports the impact of occupational characteristics on disability-free survival among a large older initially healthy population recruited from the Australian community. Among the various ISCO-88 job categories, only those belonging to the least skilled 'elementary' occupations experienced a reduction in disability-free survival. Among the specific job characteristics, work in occupations with a high accident risk or in an adverse social climate were both associated with reduced disability-free survival, and potentially contributed to health disadvantage. All-cause mortality was not substantially increased among any of the occupational groupings or with any specific occupational characteristics. This may reflect survivor bias among individuals in this age group, especially those selected for their health at baseline.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Monash University Ethics Committee (project numbers CF11/1100 and CF11/1935). 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

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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.2023.1191343/full#supplementary-material

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