What matters for health and happiness among the older adults in Asia

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What matters for health and happiness among the older adults in Asia

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Table of contents

Interaction effects of anxiety and outdoor activity spaces on frailty among nursing home residents in Jinan, China: Is there a gender difference?

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Background: Anxiety and the physical environment are critical factors influencing frailty among older adults; however, the interaction effect of anxiety and the physical environment, such as outdoor activity spaces, on frailty has not been examined. This study aimed to investigate the interaction effect of anxiety and outdoor activity spaces on frailty and to identify differences by gender.

Methods: A total of 353 nursing home residents (197 women; 156 men; age $\geq$ 60 years) from 27 Chinese nursing homes were included in the analysis. Anxiety and frailty were analyzed using the Generalized Anxiety Disorder Scale and the FRAIL-NH Scale, respectively. Outdoor activity spaces were assessed through on-site observations using self-designed items. Demographic and socioeconomic information and health-related covariates were also collected. Interaction effect analyses were conducted using multilevel mixed-effects linear models.

Results: Anxiety and outdoor activity spaces had an interaction effect on frailty among nursing home residents ($\beta = -1.32$, 95% CI: -2.44, -0.20). However, further analysis demonstrated that this interaction effect was only significant in older women ($\beta = -1.60$, 95% CI: -2.93, -0.27) but not in older men ($\beta = -0.23$, 95% CI: -2.29, 1.82).

Conclusions: This study highlighted that gender differences should be considered when preventing frailty in older adults with anxiety. Furthermore, it may be beneficial for nursing homes to provide outdoor activity spaces and create a supportive living environment to help delay or reverse frailty among female nursing home residents.

KEYWORDS

anxiety, outdoor activity spaces, frailty, older adults, gender differences

1. Introduction

Frailty is a potentially reversible state characterized by declined physiological reserves across multiple systems and accompanied by increased vulnerability to stressors (1). Individuals with frailty have an elevated risk of adverse health outcomes, including falls, hospitalization, disability, and mortality (1, 2). Compared with community-dwelling older adults, individuals residing in nursing homes might be more vulnerable and tend to simultaneously have multiple risk factors for frailty, such as comorbidities and malnutrition.

The pooled prevalence of frailty in nursing homes residents is 52.3%, which is much higher than the 10.7% reported in community settings (3, 4). Accordingly, the prevention and management of frailty could be more challenging in nursing homes. Identifying modifiable frailty factors is the first step toward formulating primary prevention and restorative strategies.

Anxiety is strongly associated with accelerated frailty and poorer health status in later life (5, 6). Anxiety has been described as a "silent geriatric giant," (7) as it is highly prevalent among older adults. Approximately 6.5–58.4% of nursing home residents are reported to experience anxiety (8, 9); however, they rarely seek help for it (10). Older adults with anxiety are more likely to report and experience health problems such as falls, pain, and chronic illnesses (11, 12), which further contribute to the occurrence of frailty. A prospective cohort study in western China including 4,103 community-dwelling older adults demonstrated that individuals with comorbid depressive and anxiety symptoms were seven times more likely to become frail than those without (5). Another study in older surgical patients revealed that anxiety was related to frailty (6). Previous studies have shown that the impact of anxiety on frailty may be reversible and avoidable (13), suggesting that anxiety is potentially a remedial risk factor for frailty. However, few studies have investigated the protective factors that help reduce frailty in older adults with anxiety. As such, it is valuable to consider factors that may aid in buffering the detrimental effect of anxiety on frailty in later life.

In more recent years, contexts have received increasing attention for their role in frailty. An emerging body of research has focused on exploring the association between neighborhood environments and frailty. Specifically, life spaces, walking environments, aesthetic quality, accessible exercise facilities, and basic infrastructure in neighborhoods are important contributors to the level of frailty (14–16). For nursing home residents, the living environment is also recognized as a vital context for residents' health. This is because they typically spend a great deal of time there and rely heavily on social connections and resources to maintain health because of their limited mobility and functioning. Particularly, during the coronavirus disease 2019 pandemic, older adults were restricted from leaving nursing homes, and institutional outdoor spaces were one of the few places for older adults to spend time outside. Hence, high exposure to outdoor environments may potentially affect the health status of nursing home residents. Theories of environmental gerontology state that individuals are influenced by an ongoing interaction between individual, social, and physical environments (17). As a consistent and proximate aspect of the physical environment, outdoor activity spaces may mitigate the effects of anxiety on frailty.

Furthermore, no studies have assessed whether the interaction effect of anxiety and outdoor activity spaces on frailty may vary by gender. Numerous studies have revealed significant gender differences in anxiety and frailty, with women having higher odds of being anxious and frail than men (18–20). Significant gender differences were also found in the association between anxiety and frailty. Compared with older men without comorbid depression and anxiety, women with anxiety alone had a higher prevalence of frailty (11). Previous literature has reported gender differences in the effect of the neighborhood environment on health. For instance, Stafford et al. (21) showed that physical characteristics of the neighborhood were more strongly associated with women's than

men's health. They suggest that the residential environment may be more important for women's health, perhaps because women have greater exposure to their neighborhood environment or are more vulnerable to its effects. Given these findings, we speculate that the interaction effect of outdoor activity spaces and anxiety on frailty is greater for women than men.

Therefore, we hypothesized that outdoor activity spaces play a role in buffering against the adverse effects of anxiety on frailty, which may exert a stronger buffering role in older women than in male residents. This study aimed to explore the interaction effect of outdoor activity spaces and anxiety on frailty among nursing home residents in China and analyse potential gender differences.

2. Materials and methods

2.1. Participants

This cross-sectional, descriptive study was conducted among nursing homes in five districts (Lixia, Tianqiao, Huaiyin, Shizhong, and Licheng) in Jinan, Shandong Province, China, from March to June 2018. Twenty-seven nursing homes were sampled for the study from the 69 nursing homes registered at the Civil Affairs Bureau with more than 30 beds and that have operated for longer than a year. Forty-two were excluded for the following reasons: refusing to participate ($n = 28$), relocating or renovating ($n = 6$), and having missing contact details ($n = 8$).

Only residents aged ≥ 60 years who had been residing in a nursing home for ≥ 3 months were included in this study. Exclusion criteria were (i) hearing impairments, communication disorders, comatose, or end-stage diseases; (ii) not residing in a nursing home during the study; and (iii) severe cognitive dysfunction as determined by a Mini-Mental State Examination (MMSE) score <10 (22). In total, 353 eligible residents were invited to participate. Details on the participant enrolment process are shown in Figure 1.

All participants were fully informed regarding the study and provided written informed consent. The study was approved by the Ethics Committee of the researchers' university (approval number 2017-R-112).

2.2. Data collection

The collection was collected anonymously. Prior to the survey, research assistants (well-trained nursing postgraduates and undergraduates) received uniform training on conducting structured face-to-face interviews and physical performance measurements, and they were asked to follow a standardized questioning sequence. After passing a minimum of 6 h of training, the research assistants were allowed to conduct the survey independently.

2.3. Measures

2.3.1. Exposure of interest: Anxiety

Anxiety was measured using the two-item Generalized Anxiety Disorder Scale (23). Participants were asked how frequently symptoms of anxiety bothered them over the past 2 weeks (0 =

FIGURE 1
Flowchart depicting participant selection process.
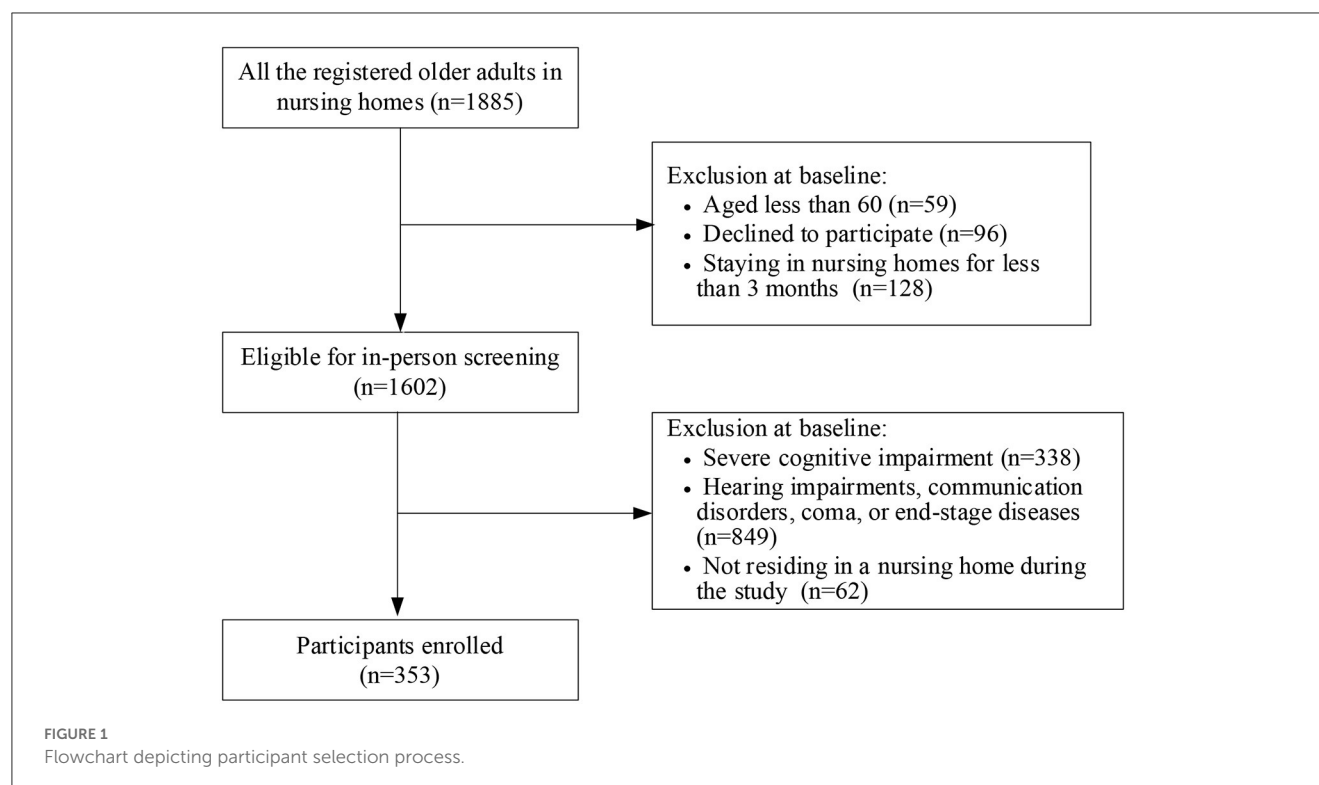
"not at all;" 1 = "several days;" 2 = "more than half the days;" 3 = "nearly every day." A total score of 0 to 2 was defined as "no anxiety," whereas a score of 3–6 was defined as "anxiety").

2.3.2. Outcome of interest: Frailty

Frailty was defined using the Chinese version of the FRAIL-NH scale (24). The FRAIL-NH scale, which includes core elements of the frailty phenotype and frailty index, is a specific measurement tool for nursing home residents. It comprises seven components: fatigue, resistance, ambulation, incontinence, weight loss, nutritional approach, and help with dressing. Each component is graded as 0, 1, or 2. The total score ranges from 0 to 14, with higher scores indicating a higher likelihood of frailty.

2.3.3. Moderator of interest: Outdoor activity spaces

Outdoor activity spaces were investigated through on-site observations by research assistants. Nursing homes were considered to provide outdoor activity spaces if they contained basic and durable fitness amenities or recreational facilities, usually installed in open spaces, such as outdoor courtyards, including spacewalk machines, leg presses, treadmills, and rotary torso machines.

2.3.4. Covariates

A priori, we identified potential covariates for adjustment based on the knowledge of factors that might causally affect

the study exposure and study outcome independent of the exposure. The demographic and socioeconomic covariates were age (years), years of education (years), marital status (married vs. single/divorced/widowed), and self-reported economic conditions (good vs. poor).

The health-related covariates included comorbidities, cognitive impairment, loneliness, and nutritional status. Comorbidities were defined as the presence of two or more chronic diseases (25). Cognitive status was assessed using the MMSE, with scores <24 indicating cognitive impairment (22). Loneliness was measured using a common five-point Likert scale that asked residents how often they felt lonely (26). This variable was dichotomised prior to statistical analyses: "sometimes," "often," and "always" represented loneliness, whereas "seldom" or "never" represented no loneliness. Nutritional status was determined using the Mini Nutritional Assessment-Short Form (27). The total scores for this assessment ranged from 0 to 14, with higher scores denoting better nutritional status.

2.4. Statistical analyses

Participant characteristics were presented as means (standard deviations) for continuous variables and frequencies (percentages) for categorical variables. Independent sample t-tests for continuous variables and the chi-squared or Fisher's exact tests for categorical variables were used to examine the differences in characteristics between men and women. As residents were clustered within nursing homes, multilevel mixed-effects linear regression models were constructed based

TABLE 1 Participant characteristics.

Variables	Overall (n = 353)	Female (n = 197)	Male (n = 156)	p
	Mean (SD) or n (%)	Mean (SD) or n (%)	Mean (SD) or n (%)	
Age (years)	79.01 (8.80)	80.93 (7.82)	76.58 (9.38)	<0.001
Years of education	5.26 (4.84)	4.52 (4.52)	8.47 (4.33)	<0.001
Marital status				0.001
Married	63 (17.8)	23 (11.68)	40 (25.64)	
Single/divorced/widowed	290 (82.2)	174 (88.32)	116 (74.36)	
Economic conditions				0.049
Good	131 (37.1)	82 (41.62)	49 (31.41)	
Poor	222 (62.9)	115 (58.38)	107 (68.59)	
Comorbidities				0.078
Yes	265 (75.1)	155 (78.68)	110 (70.51)	
No	88 (24.9)	42 (21.32)	46 (29.49)	
Cognitive impairment*				<0.001
Yes	212 (60.2)	95 (48.73)	45 (28.85)	
No	140 (39.8)	101 (51.27)	111 (71.15)	
Loneliness*				0.009
Yes	103 (29.4)	46 (24.87)	57 (36.54)	
No	247 (70.6)	148 (75.13)	99 (63.46)	
Nutritional status	9.35 (2.19)	8.99 (2.28)	9.79 (2.01)	0.001
Anxiety				0.254
Yes	60 (17.0)	38 (19.29)	22 (14.10)	
No	293 (83.0)	159 (80.71)	134 (85.90)	
Outdoor activity spaces				0.255
Provided	233 (66.0)	125 (63.45)	108 (69.23)	
None	120 (34.0)	72 (36.55)	48 (30.77)	
Frailty*	2.32 (2.49)	2.37 (2.54)	2.26 (2.43)	0.695

SD, standard deviation.
*Missing values (1 for cognitive impairment, 3 for loneliness and frailty).

on three models to test the proposed hypotheses. Model 1 was unadjusted, Model 2 included sociodemographic covariates, and Model 3 was additionally adjusted for health-related covariates. Furthermore, a margin plot was utilized to illustrate the interaction effect of anxiety and outdoor activity spaces. All analyses were performed using stratified analyses of gender to allow for possible differences in the subgroups.

We performed sensitivity analysis to evaluate the consistency of the results. To reduce the potential for reverse causality between anxiety and frailty, multilevel mixed-effects logistic regression models were re-estimated to identify the potential interaction effect between frailty and outdoor activity spaces on anxiety as well as gender differences.

Analyses were performed using Stata, version 14.1 (Stata Corp, College Station, TX). All statistical tests were two-sided, and $p <$ 0.05 was considered significant.

3. Results

Table 1 shows the descriptive characteristics of the study population. The age range of the participants was 60–103 years, with a mean age of 79.01 years, and 55.81% were women. Fifty-five participants were unable to ambulate. In total, 19.29% of women and 14.10% of men participants reported anxiety. Of the 27 nursing homes, only 15 had outdoor activity spaces. The mean frailty scores were ∼2.37 and 2.26 for women and men, respectively. Women were generally more likely to be older and single than men. Moreover, women had lower education levels, better economic conditions, worse cognitive impairment, less loneliness, and worse nutritional status than men.

The results for the association between anxiety and frailty are presented in Table 2. In the overall sample, individuals with anxiety had an increased risk of frailty compared with participants without anxiety in both unadjusted and adjusted models. Further

TABLE 2 Association between anxiety and frailty.

Model	Overall (n = 353)	Female (n = 197)	Male (n = 156)
	β (95% CI)	β (95% CI)	β (95% CI)
Model 1			
Anxiety (ref. no)			
Yes	1.86 (1.20, 2.52)‡	1.91 (1.07, 2.75)‡	1.65 (0.59, 2.71)†
Model 2			
Anxiety (ref. no)			
Yes	1.80 (1.14, 2.46)‡	1.92 (1.09, 2.75)‡	1.50 (0.44, 2.57)†
Model 3			
Anxiety (ref. no)			
Yes	1.09 (0.56, 1.62)‡	1.25 (0.59, 1.90)‡	0.76 (-0.12, 1.63)

Model 1 was unadjusted; Model 2 was adjusted for sociodemographic covariates (age, years of education, marital status, and economic conditions); Model 3 was further adjusted for health-related covariates (comorbidities, cognitive impairment, loneliness, and nutritional status). β, regression coefficient; CI, confidence interval; ref, reference group.
†p < 0.01, ‡p < 0.001.

stratification of the association according to gender revealed that men and women who experienced anxiety were at greater risk of frailty in Models 1 and 2 (women: β = 1.91/1.92, 95% CI: 1.07/1.09, 2.75/2.75; men: β = 1.65/1.50, 95% CI: 0.59/0.44, 2.71/2.57). After adjusting for all identified sociodemographic and health-related covariates, women who reported anxiety had a significantly higher risk of frailty (β = 1.25, 95% CI: 0.59, 1.90), whereas men did not (β = 0.76, 95% CI: −0.12, 1.63).

Table 3 and Figures 2–4 show the interaction effects of anxiety and outdoor activity spaces on frailty as well as gender differences. For the overall sample and for women, the significant interaction term suggested that outdoor activity spaces played a moderating role in anxiety and frailty (β = −1.32/−1.60, 95% CI: −2.44/−2.93, −0.20/−0.27). For instance, if nursing homes provided outdoor activity spaces, women with anxiety were less likely to develop frailty. However, among men, there was no significant interaction effect between anxiety and outdoor activity spaces (β = −0.23, 95% CI: −2.29, 1.82).

The sensitivity analysis revealed no interaction effect between frailty and outdoor activity spaces on anxiety and no gender differences (Supplementary Table 1).

4. Discussion

With an aging population in many countries, frailty has increasingly become an emerging public health issue. Environmental and individual factors are fundamental causes of frailty (2, 16). To the best of our knowledge, only a few studies to date have explored the cross-level interaction effects of individual factors and environmental elements on frailty as well as corresponding gender differences. This study investigated the interaction effect of anxiety and outdoor activity spaces on frailty from the perspective of individual and environment interactions and examined potential gender differences. The results demonstrated that the interaction between anxiety and outdoor

TABLE 3 Interaction effect of anxiety and outdoor activity spaces on frailty.

Model	Overall (n = 353)	Female (n = 197)	Male (n = 156)
	β (95% CI)	β (95% CI)	β (95% CI)
Model 1			
Anxiety (ref. no)			
Yes	2.94 (1.77, 4.11)‡	3.35 (2.00, 4.69)‡	1.57 (−0.79, 3.93)
Outdoor activity spaces (ref. no)			
Provided	−1.19 (−1.76, −0.63)‡	−1.45 (−2.26, −0.64)‡	−0.97 (−1.81, −0.14)*
Anxiety × outdoor activity spaces	−1.42 (−2.82, −0.03)*	−2.09 (−3.76, −0.43)*	0.28 (−2.35, 2.91)
Model 2			
Anxiety (ref. no)			
Yes	2.86 (1.71, 4.01)‡	3.25 (1.95, 4.55)‡	1.40 (−0.98, 3.77)
Outdoor activity spaces (ref. no)			
Provided	−1.12 (−1.66, −0.58)‡	−1.37 (−2.12, −0.62)‡	−0.93 (−1.76, −0.10)*
Anxiety × outdoor activity spaces	−1.43 (−2.79, −0.06)*	−2.08 (−3.71, −0.45)*	0.33 (−2.28, 2.94)
Model 3			
Anxiety (ref. no)			
Yes	2.09 (1.14, 3.05)‡	2.34 (1.25, 3.42)‡	0.98 (−0.90, 2.85)
Outdoor activity spaces (ref. no)			
Provided	−0.37 (−0.84, 0.10)	−0.66 (−1.29, −0.03)*	−0.08 (−0.77, 0.60)
Anxiety × outdoor activity spaces	−1.32 (−2.44, −0.20)*	−1.60 (−2.93, −0.27)*	−0.23 (−2.29, 1.82)

Model 1 was unadjusted; Model 2 was adjusted for sociodemographic covariates (age, years of education, marital status, and economic conditions); Model 3 was further adjusted for health-related covariates (comorbidities, cognitive impairment, loneliness, and nutritional status). β, regression coefficient; CI, confidence interval; ref, reference group.
*p < 0.05, ‡p < 0.001.

activity spaces was a significant predictor of frailty. However, the interaction effect was only observed among older women with anxiety and not older men with anxiety. This study provides practical guidance that may help nursing homes take measures to prevent and mitigate frailty among residents with anxiety. We hope that this study will encourage more researchers to explore frailty from the perspective of the interaction between the individual and the environment.

Consistent with previous findings (11, 12), our results demonstrated that individuals with anxiety were more likely to develop frailty. Although the exact mechanisms remain unclear, there are several possible underlying pathophysiological mechanisms. Growing evidence supports a positive association between anxiety and inflammatory cytokines, such as interleukin-6 and C-reactive protein (28, 29), which are known to be

FIGURE 2
Interaction effect of anxiety and outdoor activity spaces on frailty estimated based on a fully adjusted model (including age, years of education, marital status, economic conditions, comorbidities, cognitive impairment, loneliness, and nutritional status).

FIGURE 4
Interaction effect of anxiety and outdoor activity spaces on frailty among men estimated based on a fully adjusted model (including age, years of education, marital status, economic conditions, comorbidities, cognitive impairment, loneliness, and nutritional status).

FIGURE 3
Interaction effect of anxiety and outdoor activity spaces on frailty among women estimated based on a fully adjusted model (including age, years of education, marital status, economic conditions, comorbidities, cognitive impairment, loneliness, and nutritional status).

elevated in individuals with frailty (2, 30). Another explanation is hypothalamic-pituitary-adrenal (HPA) axis dysregulation. A study with older adults in Spain suggested that serum cortisol concentration was related to increasing frailty burden (31). Another study with residents of long-stay institutions in Brazil reported that salivary cortisol levels were positively associated with frailty (32). In addition, a population-based study in the Netherlands reported that older adults with anxiety had a lower cortisol awakening response than those without (33). These findings suggest that HPA axis dysregulation may increase the vulnerability of older adults to anxiety and frailty. However, in the fully adjusted model, which considered gender differences, the association between anxiety and frailty was significant only among women. Similarly, several extant studies indicated that women with mental disorders had higher levels of frailty than men (11, 34). One possible explanation for

gender differences is that women in China have lower incomes and education levels and are more likely to be widowed than men (35, 36). These factors could contribute to anxiety. Furthermore, psychological distress may increase the likelihood of frailty in women. Another possible explanation primarily linked to gender differences is biological susceptibility. Compared with men, women with anxiety reported higher serum high-sensitivity C-reactive protein (29) and diurnal cortisol levels (37), leading to loss of muscle mass, muscle strength, weight loss, and reduced energy expenditure (30), all of which are key clinical features of frailty.

We observed a significant buffering effect of outdoor activity spaces on the association between anxiety and frailty, which is supported by the aforementioned theories of environmental gerontology (17). Outdoor activity spaces provide an incentive for being physically active (38, 39), and serve as places for individuals to walk, run, dance, and perform other activities. This, in turn, may contribute to reducing anxiety and frailty risks by promoting a healthy lifestyle. Further, stress reduction theory indicates that exposure to outdoor environments may trigger the parasympathetic nervous system to reduce negative mental health outcomes, such as stress and anxiety (40). Studies have reported that access to outdoor environments is psychologically restorative and promotes mental health (39). Moreover, outdoor activity spaces create a platform for older adults to communicate and interact with others. Through the outdoor activity spaces provided by nursing homes, older adults can get out of their small living spaces and engage in social contact, which can reduce the anxiety elicited by the new environment and delay frailty. Thus, outdoor activity spaces could reduce the likelihood of frailty among older adults with anxiety.

Gender-stratified analysis indicated that outdoor activity spaces seemed to only reduce the harmful effects of anxiety on frailty in women. Self-construal theory contains an important factor that may account for this finding (41, 42). According to this theory (41, 42), men are more likely to develop and maintain an independent self-construal, in which others are represented

as separate from the self, whereas women tend to develop and maintain an interdependent self-construal, in which others are represented as part of the self (41, 42). These gender differences in self-construal could lead to divergent coping behaviors in response to psychological symptoms. Specifically, when men experience anxiety, they are more likely to actively self-regulate and cope independently and assertively. Conversely, women with anxiety are sensitive and tend to seek emotional support and social connections from interaction with others. Strong evidence exists that frailty can be prevented by an increase in social contacts (2, 19), which is more likely to occur with outdoor activity spaces, as they can facilitate social interaction. In addition, although we did not collect any information regarding the usage of outdoor activity spaces, our supplementary analysis revealed that women had a higher level of physical activity and were more likely than men to have spent their leisure time outdoors (data not shown); therefore, women could benefit more from outdoor activity spaces than men. Moreover, a recent study demonstrated that female nursing home residents had significantly higher engagement in physical activity than men (43). Physical activity is considered a promising method to reverse frailty (2); hence, outdoor activity spaces are more likely to buffer the risk of frailty in older women with anxiety.

Several limitations of this study should be acknowledged when interpreting the findings. First, the data were collected at a single time point, providing useful information about their associations but precluding any assertions of causality. Further longitudinal studies are required to establish causality by using measures at various time points. Second, participants were selected from one relatively economically developed city in China, which limits the generalisability of the study findings. Future studies are required to replicate these findings with a larger, more diverse sample of older adults, considering the great diversity in the levels of economic development, such as between urban and rural areas. Third, although we collected information on outdoor activity spaces, data on various facilities, hygiene practices, and aesthetic features of outdoor activity spaces were not available for analysis, which may affect the association between anxiety and frailty. These factors merit attention in future studies.

Despite these limitations, this study provides a novel perspective for improving the wellbeing of older adults and promoting healthy aging. Providing outdoor activity spaces could be an effective mechanism to prevent frailty among older women with anxiety. We suggest that policymakers and local governments supervise and guide nursing homes to equip outdoor activity spaces and implement activity plans, as our results found that only 15 of the 27 surveyed nursing homes provided outdoor activity spaces. In addition, some nursing homes had a small area of per capita activity space, and some were reconstructed from old buildings without consideration for outdoor activity spaces, which seriously limited residents' activities. Outdoor activity spaces could also be considered as indicators for nursing home quality evaluation. Moreover, we suggest that health providers and nursing home staff encourage older women with anxiety to visit and relax in outdoor activity spaces, as nursing home residents spend up to 65% of their time alone and are often physically inactive in their rooms (44).

In conclusion, this study represents an important first step in providing generalizable evidence regarding the effect of outdoor activity spaces on the relationship between anxiety and frailty

among older men and women. Our findings highlighted the buffering effect of outdoor activity spaces on frailty among older women with anxiety but not among men. Moreover, the study results suggest that gender differences should be considered in the prevention of frailty in older adults with anxiety. Furthermore, it may be beneficial for nursing homes to provide outdoor activity spaces and create a supportive living environment to delay or reverse frailty among female nursing home residents.

Data availability statement

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

Ethics statement

The study was approved by the Ethics Committee of the Shandong University (approval number 2017-R-112). The patients/participants provided their written informed consent to participate in this study.

Author contributions

ML and KW: supervision, writing-reviewing and editing, and critical revision. MZ: funding acquisition, conceptualization, methodology, investigation, data curation, writing-original draft preparation, and writing-reviewing and editing. TQ: investigation and methodology. YL: investigation. YW: conceptualization, investigation, and methodology. 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.2023.1133340/full#supplementary-material

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Understanding online health information seeking behavior of older adults: A social cognitive perspective

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Introduction: Online health information seeking has been verified to play a crucial role in improving public health and has received close scholarly attention. However, the seeking behavior of older adults, especially the underlying mechanism through which they are motivated to seek health information online, remains unclear. This study addresses the issue by proposing a theoretical model leveraging social cognitive theory.

Methods: IT self-efficacy and IT innovativeness were identified as personal factors and professional support and social support were identified as environmental factors. We conducted a survey that included 347 older people in China and examined the research hypotheses with a structural equation model.

Results: IT self-efficacy and IT innovativeness facilitate older adults to seek health information online by increasing their perceived benefit of using the internet. Additionally, professional support and social support enhanced older adults' online seeking behavior by promoting their health awareness. We also found that perceived benefit displayed a stronger impact than health awareness on older adults' behavior related to searching for health information online.

Conclusion: This study reveals that IT self-efficacy, IT innovativeness, professional support, and social support will promote older adults to seek health information online by enhancing their health awareness and perceived benefit. The findings of this study provide significant theoretical and practical implications.

1. Introduction

The rapid development of information technology has made the internet the most popular source of health information based on convenient access and quick response, and the number of people making use of the internet to search for health information has continued to grow. National surveys conducted in America, German, China and other countries indicated that a large proportion of internet users frequently searched for health information, totaling more than 50% of the respondents in those countries (1). Especially in the context of the COVID-19 epidemic, the internet has become the primary means as well as the best way to obtain health information.

Health information seeking behavior has been the subject of scholarly attention since the 1960's. Recently, the advent of the information technology age and internet growth have focused the spotlight on online information seeking concerning health-related topics. The term online health information seeking refers to individuals using the internet to search for

find information about their health, risks, illnesses, and health-protective behaviors. Ease of access, immediacy, and diversity of information sources are all factors that have contributed to individuals choosing online information as their preferred source for health information (2). In fact, empirical evidence demonstrates significant impacts of internet-based health information on individuals' physical and psychological health (3, 4).

In particular, scholars are paying increasing attention to older adults' behaviors related to seeking health information online (5–7). According to the World Health Organization, the population of adults over age 60 will reach 2.1 billion by 2050[1] As a result of the aging of the world's population overall, the tremendous growth of healthcare and health information needs has become a significant issue. Although seeking health information online is beneficial in addressing or solving health problems, its popularization among older adults faces many challenges due to these individuals' generally lower cognitive and technical abilities. For example, many older adults suffer a lack of technical skills and internet search skills that impedes them from using the internet to access information (8). In addition, some research has indicated that older adults tend to rely on their cognitive ability and existing medical knowledge when seeking health information; however, their cognitive abilities have been shown to typically decline with age (9). Therefore, identifying factors that can support older adults to search for health information online has major implications in both practice and research.

Although prior studies have made a great effort to identify the determinants of online health information seeking behavior (10–12), investigations into better ways to support and encourage older adults' search behavior remain scarce, and the underlying mechanisms are yet unclear. For example, some researchers identified such instrumental factors as information quality, trustworthiness, and utility of information as the dominant predictors of online health information seeking (1). However, in the case of older people, obstacles to searching for information online include a having negative attitude about the internet, entertaining poor health beliefs, and suffering IT deficiencies and low support from others (5). Thus, instead of concentrating on factors related to the health information itself, studies should pay more attention to the individual and environmental factors that directly affect older adults, such as individual cognition, IT resources, and external support. Furthermore, attaining deeper understanding of how to support older adults in searching for health information online requires exploring the mechanism through which these factors influence their health information seeking behavior.

This study addressed the above issues by drawing upon social cognitive theory to develop a theoretical research model. Two reasons support the choice of this theory for the current study. First, social cognitive theory has been widely used to explain and predict individuals' behavior and decision-making, especially in the contexts of health behaviors and information behaviors (13, 14). Second, social cognitive theory illustrates how personal factors and environmental factors simultaneously influence individual behavior (15), which fits well with the current study's research

objective. In this study, we conceptualized IT efficacy and IT innovativeness as observable personal factors and conceptualized social support and professional support as the environmental factors of interests. Next, we examined how both types of factors influenced the online search behavior of older adults seeking health information through increasing their perceived benefit of using internet and their health awareness.

This study makes several contributions to the field. For example, the findings provide a new understanding of how older adults seek for health information online from the perspective of social cognitive theory. In particular, this work is one of the first to empirically investigate how the targeted information seeking behavior is influenced by older adults' individual IT capacity and environmental support. In addition, this study clarifies the influencing mechanism through introducing the specific cognitions of perceived benefit and health awareness. This outcome fills the gap left by previous studies that focused primarily on exploring influencing factors while overlooking the underlying mechanism. Lastly, this study verifies specific personal factors and environmental factors affecting older adults based on their characteristics in the context of searching for health information online. This aspect of the current study thus complements the existing research while also providing practical suggestions on how to improve older adults' efforts on looking for health information online.

2. Literature review and theoretical background

2.1. Online health information seeking of older adults

The development of information technology has caused the internet to become the main source for health information seeking (16); as a result, many studies have focused on online health information seeking behavior. Scholars have used multiple perspectives to investigate this topic and verified its crucial role in healthcare. For example, Zhao and Zhang (17) found that health-seeking on social media could fill the demand for health information while also providing social and emotional support *via* peer-to-peer interaction.

Notably, the growth in the number of older adults and their high prevalence of health problems has attracted scholars' close attention to older adults' information seeking behavior. However, even though the positive results reported for online health information seeking, studies found that using the Internet to obtain health information is comparatively low among older adults (18). For example, research found that older adults have less trust in the Internet source and present negative attitudes toward health information from Internet (19). Moreover, older age and reduced cognitive abilities hinder older adults' access to the Internet and online health information (20). In fact, a current study illustrated that older adults relied on medical personnel, family and friends, and health brochures rather than the Internet as main sources of health information (7). Existing findings indicate that it

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FIGURE 1
Theoretical research model.
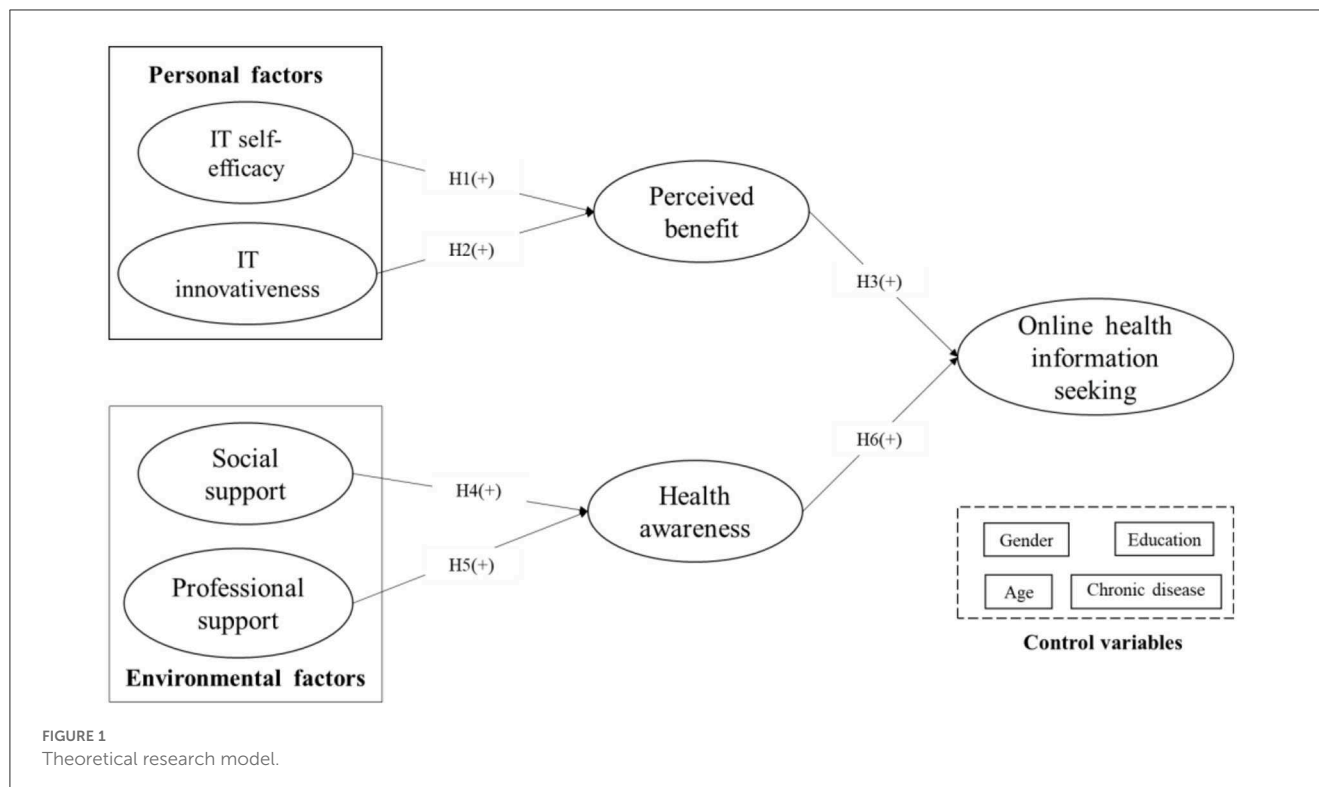
is necessary to help older adults better utilize the Internet to search for health information.

Recent studies have made great efforts to explore the motivators facilitating online health information seeking behavior of older adults. For example, Oh and Lim (21) found that communication with medical professionals significantly accelerated use of the Internet by older people to search for health information. Weber et al. (7) found that older adults' seeking behavior is related to their lifestyle, where the Average Family Person and the Sociable Adventurer use the internet more often for health information. In addition, research has found that the health condition, especially a recent diagnosis of cancer, positively facilitated older people to seek health information on the Internet (22). An empirical study by Zhu et al. (23) revealed that social support, and self-efficacy were necessary predictors of health information seeking for older adults with coronary heart disease.

However, although the current literature offers insight into factors influencing online health information seeking of older adults, few of the prior studies have yet clarified the influence mechanism (24). Improving the online seeking behavior of older people is more difficult than that of younger people because of cognitive limitations, low electronic health literacy, and negative attitudes toward technology (6). Thus, in addition to exploring the influencing factors, understanding the mechanism of influencing factors can fundamentally provide evidence for effectively promoting the online health information seeking behavior of older adults. According to previous findings, older adults' IT-related capabilities and support from their external environment are key factors affecting their behavior to search for health information online (25, 26). Consequently, this study aimed to deeply revel how personal IT-related factors and environmental

factors might influence older adults' behavior in terms of searching for health information online.

2.2. Social cognitive theory

Social cognitive theory, a classical theory that finds its basis in social learning theory, has been widely used to explain individual actions (27). This theory can be referred to as ternary reciprocal determinism; in other words, individual behaviors are determined by the interaction of three factors: person, environment, and behavior (28). In addition, these three factors can influence each other, and any two factors can influence the third factor (28). Since Bandura originally proposed the social cognitive theory, it has received ongoing examination with a focus on various individual behaviors.

The growing prominence of health issues has led to the argument that social cognitive theory should be used to achieve a healthy society (29, 30). In fact, social cognitive theory has been one of the most influential theories on health behavior (31). In particular, the key construct of social cognitive theory, self-efficacy, has been incorporated into most health behavior theories (32). Social cognitive theory addresses the environmental determinants of health as well as personal determinants and has been widely applied in the study of older adults' health behaviors and health management. For instance, based on the social cognitive theory, Borhaninejad, Iranpour (33) found that self-efficacy, social support, outcome expectations, and outcome expectancy significantly predicted diabetes self-care behaviors among the older people. In a similar vein, Zhang et al. (34) used social cognitive theory to investigate the impact of information

TABLE 1 Demographic statistics.

Variables	Category	Frequency	Percentage (%)
Gender	Male	126	36.3
	Female	221	63.7
Age	55–60	40	11.5
	61–65	78	22.5
	66–70	89	25.6
	70–75	100	28.8
	76–80	36	10.4
	Over 80	4	1.2
Education level	Middle school and below	41	11.8
	High school	185	53.5
	College	85	24.5
	Bachelor's degree and above	36	10.4
Chronic disease	Yes	214	61.7
	No	133	38.3

communication technology usage on older adults' loneliness; in their findings, the authors identified the crucial role of self-efficacy and health awareness. Social cognitive theory was also successfully applied in predicting respiratory infection prevention among older adults (35).

Existing research suggests that social cognitive theory is suitable for the study of health behavior of older adults. Although many studies have incorporated social cognitive theory, few scholars have used social cognitive theory to explore older adults' online health information seeking. In contrast, this study focused on the determinants of older adults' behaviors related to searching for health information online, giving additional attention to individual differences and environmental uncertainties. Consequently, this paper addresses the identified research gap by proposing a research model based on social cognitive theory to understand how older adults approach seeking for health information online.

3. Research model and hypotheses development

Based on the social cognitive theory, this research took personal factors (self-efficacy and IT innovativeness) and contextual factors (social support and professional support) as antecedent variables in developing a research model to verify how personal and environmental factors influence older adults' online information seeking *via* perceived benefit and health awareness. In addition, gender, age, education level, and the existence of chronic disease were included as control variables. An illustration of the proposed research model appears in Figure 1.

3.1. Personal factors

Self-efficacy, widely recognized as a critical factor that affects individual behavior, generally refers to the determination and belief that individuals can complete an action under specific circumstances and can also refer to an individual's assessment of self-ability (36, 37). The current study refers to IT self-efficacy as older adults' judgment of their ability to use information technology to locate health-related information. Older people with high IT self-efficacy are likely to experience smooth, enjoyable internet interaction and will probably obtain positive outcomes (38). Some previous studies have confirmed that self-efficacy can positively affect users' perceived value (39, 40). In the context of obtaining health information from an online source, older adults who have mastered the necessary skills to use information technology tend to access valuable health information easily and are more likely to perceive that using the Internet to seek health information is beneficial. Thus, our first hypothesis is based on the assumption that IT self-efficacy will positively affect older adults' perceived benefits.

H1: IT self-efficacy is positively related to perceived benefit.

As another consideration, innovativeness generally refers to the degree to which a person prefers to use new technologies, products, or services (41). IT innovativeness can be defined as the willingness of an individual to try out any new information technology (42). For the purposes of this study, IT innovativeness as a personal trait represents older adults' tendency to focus on and accept new information technologies or new IT functions. Prior findings suggest that individuals with higher innovativeness are able to cope with a higher level of uncertainty (43). Thus, it is reasonable to expect that a high level of IT innovativeness leads to positive experiences and outcomes from using IT. Previous research has also noted that personal innovativeness has a strong positive effect on perceived ease of use and perceived benefit (41, 44, 45). Similarly, older people who are more willing to accept and use new information technologies will probably perceive greater benefit during the health information seeking process. These observations form the basis for our second hypothesis, as follows:

H2: IT innovativeness is positively related to perceived benefit.

Perceived benefit refers to consumers' confidence that they can improve their circumstances by using certain products or services (46). In this research, perceived benefit specifically refers to older adults' perception of positive consequences by using information technologies or the Internet to seek health information. Perceived benefit is usually regarded as relative advantages, which have the capacity to meet individuals' needs or wants and further positively influence their behavior (47). Thus, it is reasonable to predict that when individuals perceive beneficial outcomes from certain behaviors, they are more likely to continue the behavior. Several previous studies have provided empirical evidence of perceived benefit significantly facilitating user behavior (48, 49). In this study, when older adults perceive that using the Internet to seek health information can meet their needs conveniently and in a timely way, their seeking behavior is likely to be encouraged. Accordingly, we proposed the following in our third hypothesis:

H3: Perceived benefit is positively related to online health information seeking.

TABLE 2 Reliabilities and correlations.

	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)	ITI	ITS	HA	OHIS	PB	PS	SS
ITI	0.942	0.963	0.896	**0.947**						
ITS	0.92	0.949	0.862	0.722	**0.929**					
HA	0.902	0.939	0.837	0.284	0.221	**0.915**				
OHIS	0.879	0.926	0.806	0.635	0.667	0.299	**0.898**			
PB	0.893	0.934	0.825	0.714	0.652	0.236	0.611	**0.908**		
PS	0.834	0.901	0.753	0.5	0.471	0.341	0.636	0.5	**0.868**	
SS	0.901	0.938	0.834	0.471	0.339	0.428	0.39	0.445	0.274	**0.913**

Bold values refer to the square roots of AVE.

3.2. Environmental factors

Social support has become an essential predictor of online health information seeking (23, 50). Social support refers to people's access to various resources provided by others through interpersonal communication, including support concerning information, assistance, and comfort (51). In this study, we specifically define social support as resources and support from family, friends, and other non-professional social peers. Scholars have widely verified that social support exerts a significant impact on individuals' health attitudes and decisions. For example, individuals will be more aware of making healthier lifestyle decisions when they receive social support through interpersonal communication (52). In addition, Choi (53) discovered that social support, such as the care of family members, will encourage individuals to actively participate in their own health maintenance. Health awareness is the consciousness to maintain one's health; thus, it is reasonable that social support is positively related to health awareness, leading to the formulation of the study's fourth hypothesis, as follows.

H4: Social support is positively related to health awareness.

Professional support means that individuals obtain help from professionals who have received professional training or education in medicine and healthcare (54). In this study, it distinguishes social support and refers to support and help from medical professionals. Since health professionals are required to master qualified and effective health knowledge, they play a crucial role in helping individuals establish positive health views, change health behaviors, and attain improved health outcomes (55, 56). When individuals receive professional support from doctors, their health problems are likely to be effectively resolved. Especially in the case of older adults, communication with health professionals enables them to access reliable medical knowledge and update their understanding of health issues, which will likely enhance their health awareness. Based on these ideas, we proposed the following:

H5: Professional support is positively related to health awareness.

Health awareness is generally used to measure the readiness of individuals to take health actions (57). People with higher health awareness tend to be more active and pay more attention to health information than their peers (58, 59). Previous studies have identified health awareness as a driver leading to healthy lifestyle change and able to affect health-related behaviors (60, 61). In

TABLE 3 Loadings and cross-loadings.

	HA	ITI	ITS	OHIS	PB	PS	SS
HA1	**0.883**	0.25	0.23	0.288	0.241	0.37	0.352
HA2	**0.939**	0.256	0.199	0.267	0.2	0.289	0.408
HA3	**0.921**	0.272	0.178	0.267	0.207	0.275	0.414
ITI1	0.26	**0.934**	0.706	0.616	0.67	0.507	0.447
ITI2	0.268	**0.942**	0.647	0.558	0.684	0.414	0.437
ITI3	0.277	**0.964**	0.699	0.638	0.674	0.5	0.453
ITS1	0.198	0.653	**0.94**	0.58	0.595	0.398	0.321
ITS2	0.186	0.65	**0.932**	0.635	0.593	0.467	0.277
ITS3	0.231	0.706	**0.913**	0.644	0.627	0.448	0.345
OHIS1	0.204	0.435	0.524	**0.817**	0.431	0.595	0.3
OHIS2	0.274	0.601	0.63	**0.934**	0.599	0.672	0.387
OHIS3	0.316	0.653	0.634	**0.935**	0.599	0.709	0.358
PB1	0.261	0.611	0.482	0.445	**0.846**	0.4	0.449
PB2	0.216	0.649	0.637	0.598	**0.932**	0.47	0.368
PB3	0.179	0.684	0.642	0.613	**0.943**	0.486	0.407
PS1	0.286	0.489	0.512	0.673	0.461	**0.896**	0.244
PS2	0.311	0.421	0.409	0.654	0.392	**0.904**	0.221
PS3	0.288	0.392	0.306	0.487	0.451	**0.798**	0.249
SS1	0.299	0.362	0.312	0.331	0.38	0.262	**0.852**
SS2	0.428	0.451	0.314	0.374	0.418	0.256	**0.94**
SS3	0.424	0.464	0.308	0.364	0.419	0.24	**0.944**

Bold values refer to item loadings of the corresponding construct.

addition, some scholars have suggested that the higher the level of an individual's health awareness, the more concerned the individual will be about his or her health, motivating the person to further engage in health-promoting behaviors (62). For the purposes of this study, online health information seeking is regarded as a kind of health behavior. Thus, it is reasonable to argue that people with higher health awareness will more actively seek health information. This argument supports the following proposal:

H6: Health awareness is positively related to online health information seeking.

4. Methodology

4.1. Data collection

To test the research model, we collected data *via* a survey that targeted to older adults who had experience using information technology to seek health information. Because the survey was conducted in mainland China, we employed the backward translation method to translate the questionnaire into the Chinese language. Before data collection began, a pilot test was conducted to ensure that the measurement would be clear and understandable to participants. According to the pilot test results, along with comments and feedback from the interviewees, we modified some descriptions and wording in the questionnaire to make it easier to understand while maintaining the original meaning.

Before surveying, we submitted the application to the university and received approval from the academic board. We then distributed the modified questionnaires to older people in some residential communities in Northeast China. We worked with neighborhood committees who assisted us in recruiting participants, instructing participants to fill in the questionnaire, and collecting the responses. Before joining the study, all participants were informed the purpose of the survey and voluntarily choose whether to participate. To ensure the accuracy and validity, interviewees in the polit test were excluded. Once they agreed to participate, participants were given a paper questionnaire, along with a research staff who explains precautions and assists in filling it. The survey was anonymous, and participants were assured that the data collected will be kept confidential and used only for academic research, which encourages participants to answer the questionnaire as truthfully as possible. The survey was conducted on-site, where participants were rewarded with two eggs after completing the questionnaire. Completed questionnaires were collected and sent back directly to our research team for quality review and data analysis.

Out of 500 questionnaires that were distributed, 405 questionnaires were obtained after removing incomplete responses, rendering an 81% response rate. Since the objective of this study concerned the older segment of the population, respondents who were younger than 55 years old were excluded. The rationale is that the legal retirement age for females in China is 55, which is also widely identified as the age of older adults in numerous studies (63–65). Additionally, the questionnaire began with the screening question, "Have you experience in seeking health information using information technology or on the Internet?" If a respondent answered, "No," the questionnaire was considered invalid. To further improve the validity of the questionnaires, we eliminated questionnaires that repeated more than 75 percent of the answers. A final total of 347 valid questionnaires was obtained for further analysis. We compared the demographics such as age, gender, and education between first 100 and last 100 respondents and found no significant differences, indicating that non-response bias was not a factor in this study. Table 1 presents the demographics information of the respondents.

4.2. Measurement

All measures of constructs in this study were adapted from previous studies and were appropriately modified to fit the current research context. Specifically, online health information seeking (OHIS) was measured with three items adapted from Cao et al. (66). Perceived benefit (PB) refers to older adults' perceived benefit of using IT to seek health information, which was measured with three items adapted from Al-Debei et al. (47). In addition, health awareness (HA) was measured with items adapted from Guo et al. (67), reflecting the health concerns and consciousness of the older adults. IT self-efficacy (ITS) and IT innovativeness (ITI), two constructs representing the personal IT resources of the study participants, were measured with items adapted from Thatcher and Perrewe (68) and Zhang et al. (69), respectively. Social support (SS) refers to the support that the participants received from family, friends, and social networks, which was measured with items adopted from Zimet et al. (70), while professional support (PS) refers to support from doctors and other medical professionals and was measured with items from Rosland et al. (71). All measurement items are specifically listed in the Table A1. Seven-point Likert scales were employed, ranging from 1 (strongly disagree) to 7 (strongly agree).

5. Data analysis and results

In this study, we used structural equation modeling (SEM) with the partial least squares (PLS) algorithm to analyze the collected data and evaluate the research model. PLS-SEM is relatively robust in survey data analysis while considered more suitable for testing models with small sample sizes (72); therefore, this method was deemed suitable for this study. SmartPLS 3.2 software was employed as our analytic tool. Following two-step procedures, we first examined the measurement model to ensure its reliability and validity, then examined the structural model to confirm the hypothesized relationships.

5.1. Measurement model

To assess the measurement model, we examined the reliability, convergent validity, and discriminant validity of our constructs. The reliability of constructs was assessed by checking whether composite reliability and Cronbach's alpha were higher than the threshold of 0.7. As shown in Table 2, composite reliability and Cronbach's alpha of all constructs were >0.7, indicating good reliability (73). Convergent validity was assessed by the item loadings and the average variance extracted (AVE) from expected constructs, which needed to be higher than 0.7 and 0.5, respectively (73). Table 3 reveals that all item loadings of constructs were >0.7; meanwhile, Table 2 shows that all AVE values were >0.5, thereby suggesting good convergent validity. Two approaches were employed to assess the discriminant validity. First, we compared whether the square root of AVE for a construct was greater than the correlation coefficients between the expected construct and other constructs. As shown in Table 2, all constructs satisfied the

criterion. Second, we compared whether the item loadings of a construct were higher than the cross-loadings, which was verified by the results presented in Table 3. These results indicated that constructs in this study had good discriminant validities (74, 75).

To further test the potential problem of multi-collinearity for constructs, we calculated variance inflation factor (VIF) values. According to the results, VIF values for all constructs ranged from 1.059 to 2.052, less than the suggested criteria threshold of 3.3 (76). Thus, multi-collinearity was not an issue in this study. In addition, to test for common method bias, we used Harman's single factor test to examine whether a single component accounted for most of the variance (77). The results indicated that the most variance explained by one factor was 36.8%, which was lower than the 50% threshold, thus indicating that common method bias is not a concern.

5.2. Structural model

Figure 2 depicts the structural model results. For personal factors, both IT self-efficacy ($\beta = 0.285$, t $= 4.621$, $p < 0.001$) and IT innovativeness ($\beta = 0.508$, t $= 9.168$, $p < 0.001$) had a positive significant effect on perceived benefit, supporting H1 and H2. The results demonstrate that perceived benefit ($\beta = 0.589$, t $= 13.373$, $p < 0.001$) significantly promoted online health information seeking behavior, supporting H3. In addition, for environmental factors, social support ($\beta = 0.361$, t $= 6.811$, $p < 0.001$) and professional support ($\beta = 0.242$, t $= 4.284$, $p < 0.001$) were verified to positively impact health awareness, supporting H4 and H5, respectively. Meanwhile, health awareness ($\beta = 0.177$, t $= 3.726$, $p < 0.001$) showed a positive effect on online health information seeking. Overall, the structural model explained 45.5% of the variance in online health information seeking, along with 54.9% of the variance in perceived benefit and 23.7% of the variance in health awareness. Lastly, among the control variables, gender and chronic disease revealed a positive effect on online information seeking, indicating that female older adults and older adults with chronic disease were more likely to seek health information online.

5.3. *Post-hoc* analysis

The structural model results indicated that perceived benefit and health awareness simultaneously determined online health information seeking; specifically, perceived benefit was influenced by IT self-efficacy and IT innovativeness, while health awareness was influenced by social support and professional support. To further reveal the underlying influence mechanism, we went on to examine whether mediating effects existed in the research model. Employing the PROCESS, a widely used tool developed by Hayes (78) to estimate models with mediators, we tested the mediation effect of perceived benefit and health awareness. As presented in Table 4, both perceived benefit and health awareness demonstrated significant partial mediating effects. Specifically, the effects of IT self-efficacy and IT innovativeness on online health information seeking were partially mediated by perceived benefit. Similarly, the

effects of social support and professional support on online health information seeking were partially mediated by health awareness.

Furthermore, the results for the structural model visually demonstrated that the influence path coefficient ($\beta = 0.589$) between perceived benefit and online health information seeking was greater than the path coefficient ($\beta = 0.177$) between health awareness and online health information seeking. We further statistically verified whether there were differences in the effects of perceived benefit and health awareness on online health information seeking. Using the approach proposed by Keil et al. (79), we discovered that the difference in path coefficients between perceived benefit and health awareness on online health information seeking was significant (t $= 116.384$). Thus, perceived benefit was shown to play a more important role than health awareness in promoting older adults to seek health information online. Similarly, we also compared the effects of IT self-efficacy and IT innovativeness on perceived benefit, as well as the effects of social support and professional support on health awareness. The results in Table 5 indicate that IT innovativeness exerted a stronger impact than IT self-efficacy, while social support exhibited a stronger impact than professional support.

6. Discussion
6.1. Key findings

Drawing upon social cognitive theory, this study investigated the effects of personal and environmental factors on the online behavior of older adults seeking health information and uncovered the influencing mechanism. The results elicit several key findings. For example, the study findings verified that IT self-efficacy and IT innovativeness are two crucial personal factors for older adults in promoting their online behavior when seeking health information; in particular, IT innovativeness was identified as having a stronger impact. This finding is in line with practice and previous studies that have emphasized the importance of IT capacity and resources in older adults' behavior related to searching for health-related information online (8).

This study also confirmed two significant environmental factors: social support and professional support. Our results indicated that both factors showed positive impacts whereby the effect of social support was stronger, demonstrating that support from doctors, families, and friends can encourage older adults to actively seek health information. This observation complements the findings of previous studies that less communication with professionals and families leads to online health information seeking (21, 80). We empirically found that support from professionals and families was significantly positively related to older adults' online health information seeking.

Our results also validate the direct effect and mediating role of perceived benefit and health awareness for older adults. Specifically, when such individuals believe that using IT is beneficial and experience a high level of health awareness, they tend to seek health information online. In particular, the perceived benefit of using IT to seek health information revealed a much stronger impact on older adults' behavior than health awareness. Furthermore, the effects of IT self-efficacy and IT innovativeness on online
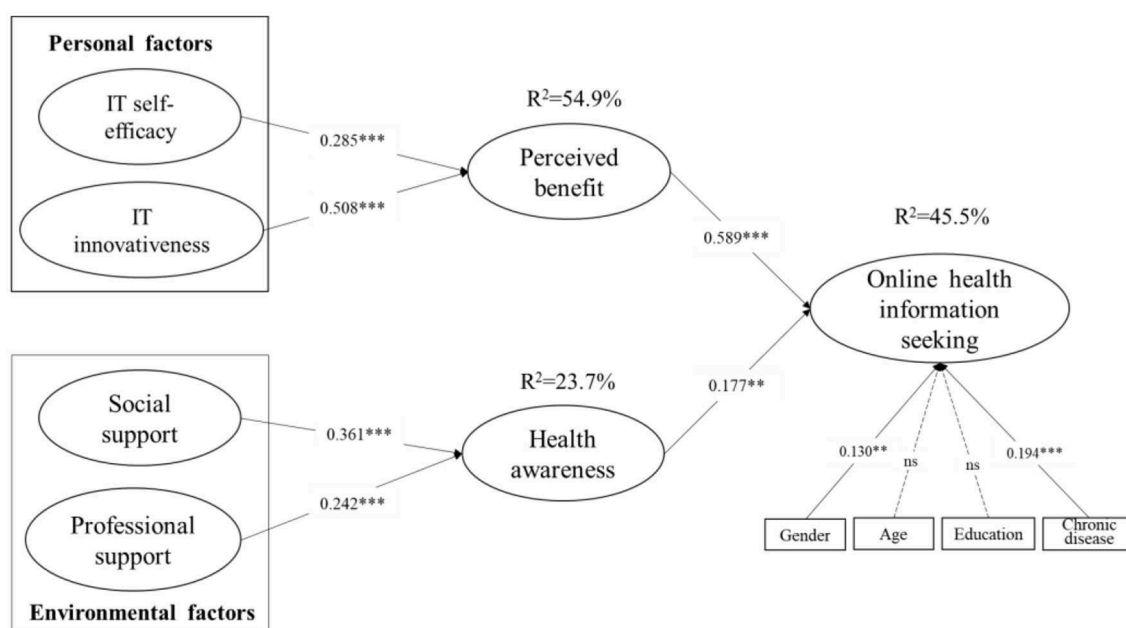
FIGURE 2
Structural model results. ***p < 0.001, **p < 0.01.

TABLE 4 Mediation effect test.

Mediator	Path	Indirect effect (95%)			Direct effect (95%)			Results
		Size	LLCI	ULCI	Size	LLCI	ULCI	
PB	ITS->PB->OHIS	0.186	0.1090	0.2625	0.463	0.3558	0.5592	Patrial mediating
	ITI->PB->OHIS	0.215	0.1189	0.3069	0.399	0.2887	0.5090	Partial mediating
HA	SS->HA->OHIS	0.067	0.0201	0.1144	0.315	0.2107	0.4195	Partial mediating
	PS->HA->OHIS	0.038	0.0067	0.0481	0.474	0.4933	0.6564	Partial mediating

health information seeking were partially mediated by perceived benefit, while the effects of social support and professional support on online health information seeking were partially mediated by health awareness.

6.2. Theoretical implications

This study contributes to the field by raising several theoretical implications. First, this study enriches the research on online health information seeking through investigating older adults' online health information seeking behavior. Although a few scholars previously sought to understand older adults' attitudes toward searching for health information online (80, 81), they mainly explored and summarized the factors influencing older adults' behavior while neglecting to interpret how these factors motivated their subjects to seek health information online. As far as we know, our study is one of the first to address this issue. In particular, due to older adults' characteristics, their means of obtaining health information is usually passive when compared to young people (82). Therefore, clarifying the mechanism underlying older adults' online health information seeking can shed light on how to

effectively facilitate this process for them while, at the same time, deepening the scholarly understanding of this issue.

Second, this study empirically confirms the antecedents of online health information seeking by contextualizing older adults' specific drivers. Drawing on social cognitive theory, we integrally examined antecedents from personal and environmental perspectives. Although factors such as IT self-efficacy and social support have been identified as playing significant roles in determining online health information seeking (10, 66), this study takes a further step by empirically verifying their effects on older adults' behavior. Based on the framework of social cognitive theory, we also authenticate the significant role of IT innovativeness and professional support. Furthermore, we clarify the differential impacts of antecedents by comparing their effects, revealing the underlying influence paths. Thus, this study not only comprehensively highlights the impacts of different determinants but also provides new understanding and suggests directions for future research.

Third, this study contributes to social cognitive theory by introducing it in the online health information seeking context and validating the mediation role of perceived benefit

TABLE 5 Path coefficients comparison.

DV	Path	Path coefficient	T value	Conclusion
OHIS	$\beta_{PB->OHIS}$ vs. $\beta_{HA->OHIS}$	0.589*** vs. 0.177***	116.384***	$\beta_{PB->OHIS} > \beta_{HA->OHIS}$
PB	$\beta_{ITS->PB}$ vs. $\beta_{ITI->PB}$	0.285*** vs. 0.508***	50.135***	$\beta_{ITS->PB} < \beta_{ITI->PB}$
HA	$\beta_{SS>HA}$ vs. $\beta_{PS->HA}$	0.361*** vs. 0.242***	4.755***	$\beta_{SS>HA} > \beta_{PS->HA}$

***$p < 0.001$.

and health awareness. Although social cognitive theory has been widely applied in studies examining health behaviors (83, 84), to our knowledge, no other scholars have previously investigated online health information seeking from the perspective of social cognitive theory. This study fills a gap in the literature by providing a deeper understanding of how older adults' personal factors and environmental factors comprehensively influence how they search for health information online. Furthermore, this study certifies that older adults' cognitions and perceptions (i.e., perceived benefit and health awareness) significantly mediate the impacts of personal factors and environmental factors on behavior. In this regard, this study enriches the previous understanding of social cognitive theory by revealing the influence mechanism of personal and environmental factors.

6.3. Practical implications

The findings of this study lead to some practical suggestions to aid the public, especially older adults, in actively seeking health information online. For example, results illustrated that both perceived benefit and health awareness significantly enhance older adults' search behavior, suggesting managers and organizations should take corresponding measures to improve older adults' evaluation of information technology and promote their health awareness. Accordingly, to enhance perceived benefit, health information technology service providers are encouraged to develop and optimize health information seeking functions to improve user-friendliness, such as increasing front size, simplifying search interface, and adding guidance-related notes for older adults. These tips will improve user-friendliness and are likely to increase older adults' perceived benefit and further promote online health information seeking. In addition, since health awareness is positively related to health information seeking behavior, organizations and governments are encouraged to organize health lectures and strengthen health publicity to improve older adults' health awareness.

Moreover, IT self-efficacy has been found to play a significant role in older adults' perceived benefit and online health information seeking, thus practitioners should address the issue of improving older adults' IT-related abilities. Along these lines, health information technology companies are advised to set up a special department for older adult users and send staff to train such individuals on how to effectively use the Internet to obtain health information. Furthermore, since IT

innovativeness significantly increases perceived benefit and further promotes information seeking, we recommend that information technology designers should develop exploratory features for older adults to improve their innovativeness. For example, developing exploratory games and displaying them on login screens to encourage older adults act in a more innovative way.

Lastly, results in this study demonstrated that social support and professional support significantly enhance older adults' health awareness and further facilitate their efforts to find relevant health information. Therefore, we strongly suggest that healthcare workers and people surrounding older adults (e.g., family and friends) should provide more support in terms of their health management. According to our findings, a family doctor is necessary for older adults, allowing them to obtain professional information and medical support on a regular basis. Similarly, since social support was shown to have a stronger positive impact on older adults' health awareness, we suggest that families and friends offer more help and care to older adults, for example, keeping an eye on their health and discussing health issues with them regularly.

6.4. Limitations and future research

Although several notable theoretical and practical implications emerged from the study findings, some limitations should be addressed, which lead to suggestions for future research. For example, this study used a cross-sectional survey to examine the research model. Although tests were conducted to verify that the results were not affected by common method bias and multicollinearity, future research is strongly recommended using mixed methods and a longitudinal design to confirm the causal relationships. Furthermore, the research was conducted on the Chinese mainland, potentially limiting the generality of the research results. In particular, older Chinese adults prefer collectivism in which social support is more likely to play significant roles. Future research should therefore take cross-cultural issues into account to reach more interesting findings. Lastly, drawing on social cognitive theory, we captured IT self-efficacy and IT innovativeness as personal factors and incorporated professional support and social support as environmental factors. However, technology characteristics, such as the user-friendliness of information technology, may also play significant roles and are worth investigating in 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.

Ethics statement

The studies involving human participants were reviewed and approved by Ethical Committee of the Harbin Institute of Technology (N.2021-10 dated on 8th of November 2021). The patients/participants provided their written informed consent to participate in this study.

Author contributions

XM and PZ: conceptualization, methodology, and writing. YL and RQ: methodology and writing. FM: review, editing, and supervision. 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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Appendix

TABLE A1 Survey instruments.

Construct	Questions	Reference
Online health information seeking	I frequently find health information online.	(66)
	I often use health websites.	
	I often seek health information on the internet.	
Perceived benefit	By using internet, I can seek health information in privacy conveniently.	(47)
	I can seek health information online whenever I want.	
	Seeking health information online can save me the time and effort.	
Health awareness	I reflect about my health a lot.	(67)
	I am very self-conscious about my health.	
	I am generally attentive to my inner feelings about my health.	
IT self-efficacy	I can complete the task such as seeking health information using internet if… (1) …there was no one around to tell me what to do	(68)
	(2) …I had seen someone else using it before trying it myself.	
	(3) …someone showed me how to do it first.	
IT innovativeness	I am willing to try new information technologies.	(69)
	I think it is very interesting to try new information technologies.	
	I enjoy trying new information technologies.	
Social support	I can talk about my health problems with my family and friends.	(70)
	My family and friends are willing to help me in my health.	
	I get the help and support I need from my family and friends.	
Professional support	I can get the support I need from doctors and other health professionals.	(71)
	I can account on doctors to help and support me a lot with health problems.	
	I am satisfied with support from doctors and other health professionals.	

A study on the influence of community spiritual comfort service on the mental health of older people

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Background: China is experiencing rapid population aging, with the proportion of older adult people aged 60 and above reaching 19. 8% of the total population in 2022. With the growth of age, the physical function of older adults declines and their mental health is getting worse, with the increasing trend of empty nesting and childlessness, older adults lack information and social interaction with others and fall into social isolation, loneliness and some mental health problems, the proportion of older adults with mental health problems gradually rises and the mortality rate increases incrementally, requiring effective ways to intervene in the mental health of older adults and promote healthy aging.

Aim of the study: The present study investigated the influence of spiritual comfort older adult services on the mental health of 12,624 older adults aged 60 years or older in 23 provinces in China from 2017 to 2018, with the aim of providing a case for the development of more targeted mental health strategies for older people.

Methods: Using the data from the 2018 CLHLS Survey, the influencing factors of the mental health of older people were analyzed using chi-square test and the logit regression model. The mechanism of the health care facilities and the spiritual comfort services on mental health was analyzed using the chain mediation effect.

Results: The spiritual comfort services decreased the risk of negative emotion and mental health of older adults, with female (OR = 1.168), rural residents (OR = 1.385), no drinking (OR = 1.255), not exercising (OR = 1.543), not having pension insurance (OR = 1.233), and low annual household income (OR = 1.416) being the characteristics as risk factors. The mediating effect results showed that the health care facilities had a partial mediating effect between the spiritual comfort services and the mental health status of older people, and the mediating effect accounted for 40.16% of the total effect.

Conclusions: The use of spiritual comfort services can effectively reduce and alleviate the adverse mental health symptoms of older people, promote guidance and health education for healthy older people and chronically ill patients, and improve the good health perception of older people in order to improve their quality of life and mental health status.

KEYWORDS

mental health, spiritual consolation, the mediation effect, health care facilities, emotional characteristics

Introduction

In recent years, the aging population has seriously hindered the development of the world economy. China is the largest developing country in the world and have the largest number of older people in the world right now, and this will continue 2,050 and beyond (1). According to statistics, more than 20% of adults aged 60 and over suffer from mental or neurological disorders (2), and the lifetime prevalence rate of any mental health problem in China is 16.6 % (3). The physical and mental health and quality of life of older adults has become an important issue for society, and researchers are increasingly concerned about how care services can support an aging society and promote the lives and health of older adults (4, 5). While older adults fall into social isolation, loneliness and some mental health problems due to retirement, physical health problems and other reasons, older adults lack information and social interaction with others (6, 7). In particular, the blockade and social distance during the COVID-19 led to depression in many older adults (8), who are at higher risk of developing serious diseases, with a mortality rate of 3.6% for those aged 60–69 years, increasing to 18% for those over 80 years (9). In addition, the social consequences of isolation are considered. Social disconnection is particularly important for older adults who are less accustomed to digital technology, as it may limit social activities, interfere with daily life, increase substance use, and reduce sensory stimulation. All these conditions combined with isolation may have a negative impact on the mental health of older adults.

In this context, China's social senior service system proposes to build a social senior service system based on home-based senior care, community-based senior care, institutional senior care as a supplement, and the combination of medical care, and proposes a "9,073" senior service pattern, that is, home care services provided by the family accounts for 90%, senior service provided by the community accounts for 7%, and senior services provided by the institution accounts for 3%.Community senior services, as an important part of senior service policy system, basing on living environment and family, can provide specialized services such as day care, medical rehabilitation, nursing care, spiritual comfort and recreational activities for older people and reduce their physical health burden, especially, spiritual comfort services can promote the social participation of older people, as well as improve their sense of health and wellbeing and access. The spiritual comfort demand of older people refers to the psychological needs of older people in terms of emotional communication, social interaction and self-actualization after retirement in order to relieve their misery, change their monotonous life and realize their own value (10). Some scholars have explored the role of community spiritual comfort senior services on the quality of life of older people, and concluded that community spiritual comfort senior services can have a positive impact on the wellbeing of older people and significantly improve their mental health (11). Compared to older adults who do not enjoy community services, those who receive community-based spiritual comfort services have higher life satisfaction (12), and a well-established supportive community environment for older adults can effectively alleviate the adverse effects on mental health and has a significant psychological building effect (13), thus reducing their negative psychological problems such as loneliness and helplessness, depression, anxiety and depression, which have a positive impact on improving the quality of life of older people and extending their healthy life span.

Mental health has always been a prominent problem for older people in China, and scholars have begun to pay attention to the factors influencing the mental health of older people, in an effort to gain a more comprehensive understanding of the root causes of their mental problems, address their mental illnesses, and improve their mental health. The factors affecting the mental health of older people can be summarized as individual characteristics, lifestyle habits (smoking, drinking, exercise, etc.), social relationships (family relationships, interpersonal relationships, etc.), economic status (income level, social security), etc. The mental health status of older adults tends to vary depending on the type of residence or the way they age. Compared to institutional care, the mental health of older adults who age at home and in the community is significantly better (14), and living with their daughters is the most beneficial to the mental health of older adults (15). In terms of social factors, some scholars' studies found that social support from family, neighbors, and friends influenced older adults' subjective wellbeing and mental health by affecting their sense of self-esteem and loneliness (16). In terms of economic factors, Su Hong's study all showed that economic income had a positive impact on the psychological wellbeing of empty- and non-empty-nesting older adults (17). The coping capacity of older adults in this study includes health care facilities at both the family and social levels, health care facilities at the family level reflects the informal care of the older adults by relatives and friends, and health care facilities at the social level reflects the function of mutual help and risk regulation (e.g., social support, medical accessibility), and the improvement of the health care facilities of older adults is important for alleviating or regulating the mental health condition of older adults (18).

This study explores the factors influencing the mental health of older adults and the mechanism of the influence of spiritual comfort services on the mental health of older adults using data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2018. The aim is to alleviate the mental health vulnerability of older people, improve their mental health and quality of life, and provide some reference for vigorously promoting "healthy aging" and improving the mental health of older people in China.

Theoretical basis

Research on the relationship between community-based spiritual comfort services and the mental health status of older people has started earlier by domestic and foreign scholars, and related studies mainly hold positive theories. It has been shown that health interventions in spiritual comfort services improve the self-rated health status of older adults, with general improvements in mental health and a reduced incidence of anxiety (19), contributing to improved physical and mental health, wellbeing, and social support for vulnerable populations. A study of senior depressed patients found that community-based spiritual comfort services effectively managed senior patients from medical, functional, and social perspectives, which not only contributed to the early detection and treatment of depression, but also to the rational

use of primary care resources (20). In addition, the provision of community-based spiritual comfort services contributes to improving the quality of care and life of older adults and enhancing their physical functional capacity, while increasing communication with the outside world, diminishing the sense of loneliness and isolation, and making a significant contribution to improving their mental health.

Social support can facilitate the exchange of psychosocial resources for older individuals and frail individuals, such as emotional or instrumental support among members of society, thus promoting mental health (21). At the community level, social support enables older age groups to organize and act collectively, and facilitates the creation of new social ties and cohesion. The findings suggest that there is an increasing tendency for older adults to live alone due to changes in demographics, social welfare systems, and family culture, and that older adults' health is not necessarily at risk if they maintain social ties outside the home and avoid social isolation. Loneliness and social isolation may also lead to many problems such as depression, cognitive dysfunction, disability, cardiovascular disease, further exacerbating pre-existing health conditions, and increased mortality in older adults (22).

Therefore, health care facilities has become an important influencing factor on the health behavior, emotional health, and cognitive level of older adults from the current study, and may be an important mediator of the level of mental health between community-based spiritual comfort services and older adults, as well as an explanatory mechanism by which the provision of community-based spiritual comfort services affects the mental health of older adults (Figure 1).

Materials and methods

Data source

The data used in this study were obtained from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which was organized and implemented by the Center for Healthy Aging and Development Research/National Development Research Institute of Peking University. The survey covered 23 provinces across China, and the survey population was mainly older people aged 60 years and above. The survey mainly collected data related to basic information, socio-economic background and family structure, economic sources and economic status, self-assessment of health and quality of life, cognitive function, personality characteristics, daily activity ability, lifestyle, life care, disease treatment and medical cost bearing of older people and their families. A total of 15,874 older adults aged 60 years and older were surveyed in the CLHLS database in 2017–2018, and information on individual physical health indicators such as daily mobility, subjective feelings, and physical functional status, individual personality and emotional perceived mental health indicators, community senior services, and the health care facilities of older adults were selected as study variables in this study, samples with a large number of missing values for the main variables and samples with outliers over 120 years of age were removed, and data with missing values <5% of the overall sample were filled by interpolation in Stata 15.0 in order to maximize the use of available survey information, resulting in a valid sample size of 12,624. This study used SPSS25.0 for the internal consistency of the demand for community-based spiritual comfort services, and the result was Cronbach's coefficient of 0.828 (Table 1), indicating that the questionnaire passed the reliability analysis. Validity analysis is to verify the validity of the data, and is used to detect whether the results of the questionnaire measurement can correctly reflect things. SPSS25.0 was used to test the validity of community spiritual comfort services, and the KMO was 0.872, and the significance of Bartlett's sphericity test was $P=0.000$, indicating that the questionnaire has high validity (Table 2). The detailed sample selection process is presented in Figure 2.

TABLE 1 Reliability analyze.

Cronbach's alpha	Item
0.828	3

TABLE 2 Validity test of community spiritual comfort service.

KMO		0.872
Bartlett test of sphericity	Approximate chi-square	6,880.660
	df	3
	Sig.	0.000

FIGURE 1
Theoretical framework diagram.
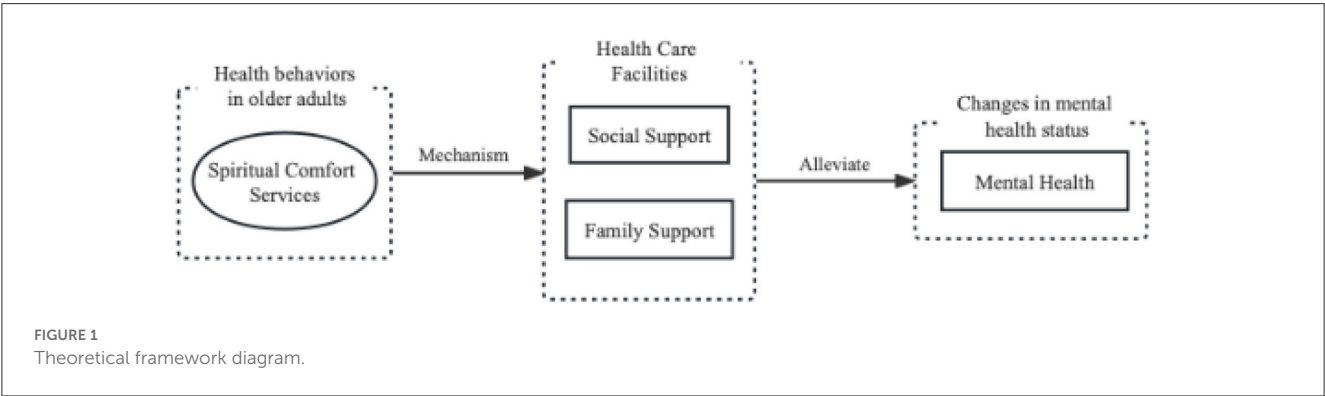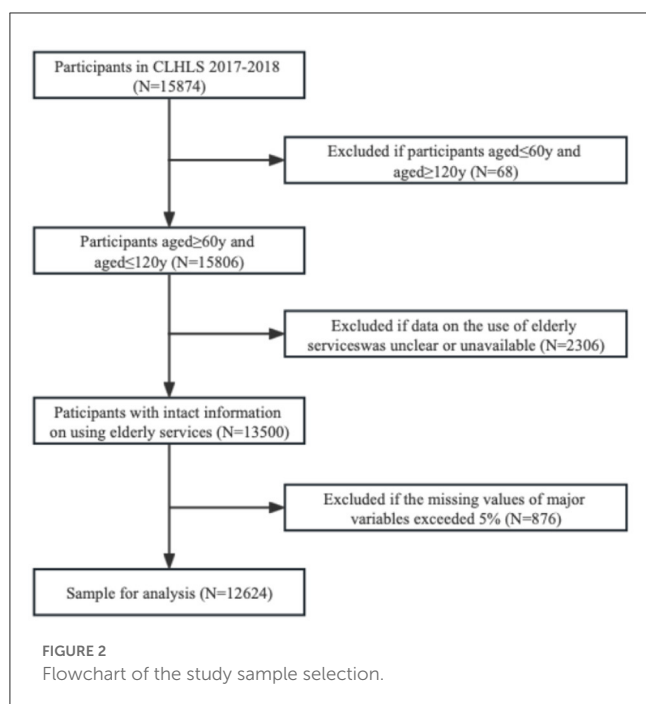
Measurement of mental health

Based on the existing methods of measuring mental health of older people, the mental health of older people was divided into four dimensions of emotional characteristics, geriatric anxiety, geriatric depression and cognitive impairment to measure the mental health vulnerability representations of older people (18). Among them, the emotional characteristics were measured by the CLHLS questionnaire "Can you always think about whatever happens to you? Depression was assessed by the CESD-10 scale, and a score of <10 was considered as having no depressive symptoms, and a score of more than or equal to 10 was considered as having depressive symptoms (23), the scale's Cronbach's alpha was an excellent 0.836 in the current sample. Anxiety was assessed by the GAD-7 scale, and a score of <10 was considered as having no anxiety symptoms, and a score of more than or equal to 10 was considered as having anxiety symptoms (24), the scale's Cronbach's alpha was an excellent 0.927 in the current sample. Cognitive impairment was assessed by using four modules of CLHLS: general ability, reaction ability, attention and calculation ability, recall, language, comprehension and self-coordination ability, and the correct answers were summed up, the scale's Cronbach's alpha was an excellent 0.936 in the current sample (Table 3). Meanwhile, JunNing Fan's index calculation method was referred to calculate the mental health index of older people, in order to examine the characteristics of mental health of older people, and each variable was dichotomized or mapped to the 0.00–1.00 interval, with 0.00 indicating no deficits (the healthiest state) and 1.00 indicating the greatest deficits (the least healthy state), while the index was calculated by summing the deficit scores of the different dimensional indicators of the older individual divided by the highest score of the four indicators included, according to the consensus of constructing the index, without assigning weights to

variables related to each other (25), which was used to respond to the mental health representations of older individuals, with a mental health index >0.25 being classified as fragile and a mental health index <0.25 being considered healthy.

Socio-demographic information

This includes demographic characteristics (age, sex, type of household, marital status), family status (living style, care by relatives and friends), lifestyle (smoke or not, drink or not, whether to exercise), economic status (pension insurance, social and commercial insurance, annual household income). Based on existing studies, five dimensions of the CLHLS questionnaire were used to define the health care facilities of older people: routine medical checkups, pension insurance, accessibility to medical care, living alone, and care by family and friends. Among them, "Do you have a regular medical checkup once a year¿' as a measure of regular medical checkups, pension insurance based on the question "Are you enrolled in pension insurance¿' and "If you are seriously ill, can you get to the hospital in time¿' as a measure of medical accessibility; whether you live alone based on the question "Do you currently live alone¿' measured by the question "Currently, do you have someone to take care of you when you are not feeling well or when you are sick¿' measures care by a friend or relative and is assigned a value of 1 if the older person has this coverage, otherwise it is assigned a value of 0.

Spiritual comfort senior service includes spiritual comfort chatting and relief service, organizing social and recreational activities service, and dealing with family and neighborhood disputes service. The independent variable was whether older people had used spiritual comfort services, if older people have used at least one of three seniors care services, the value is 1, otherwise the value is 0.

Statistical methods

Stata 15.0 was used for data collation and statistical analysis, descriptive statistical analysis and logit regression analysis were conducted on the individual characteristics, family status, lifestyle, and economic situation of the study subjects, chi-square tests were used to examine the general characteristics differences between healthy and unhealthy subjects according to the distribution of categorized variables. Count and percentages were used to describe categorical variables, and Amos 23.0 was used to establish a structural equation model to analyze the influence mechanism of mental health of older people, and to explore the influence of spiritual comfort type of senior services on the mental health status of older people. The difference was considered statistically significant at $P < 0.05$.

Model construction

This study used logit regression modeling and structural equation modeling, respectively, in order to investigate the

TABLE 3 Indicator definition and assignment.

Values		Indicator definition	Variable assignment
Mental health	Cognitive impairment	Do you always look on the bright side of things?	Always = 0, often = 0.25, sometimes = 0.5, seldom = 0.75, never = 1
	Geriatric depression	CESD-10 scale	Score≤10 points is 0, score>10 is 1
	Geriatric anxiety	GAD-7 scale	Score≤10 points is 0, score>10 is 1
	Emotional Characteristics	Orientation, registration, attention and calculation, recall, language	Add up the correct answers and assign a score of 1 for 0–10, 0.75 for 11–16; 0.5 for 17–20, 0.25 for 21–23, 0 for 24
Health care facilities	Medical accessibility	Can you get adequate medical service when you are sick?	Yes = 1, No = 0
	Routine medical examination	Do you have regular physical examination once every year?	Yes = 1, No = 0
	Pension insurance	Do you participant in public old age insurance?	Yes = 1, No = 0
	Care by family and friends	When you are sick, is there someone to take care of you?	Yes = 1, No = 0
	Living alone or not	Co-residence	Yes = 1, No = 0

mechanism of the effect of spiritual comfort type of senior services on the mental health of older people.

Among the explanatory variables of the logit model were emotional characteristics of older adults, geriatric depression, geriatric anxiety, and cognitive impairment. The model expressions are as follows.

$$Health_i = \beta_0 + \beta_1 Spiritual_i + \sum_{j=2} \beta_j X_i + \varepsilon \quad (1)$$

where $Health_i$ represents the emotional characteristics, geriatric depression, geriatric anxiety and cognitive impairment of older people, β_0 is an intercept term, $Spiritual_i$ represents spiritual comfort type of senior services, X_i represents sociodemographic variables including Individual Characteristics, Family Status, Lifestyle and Economic Status, and ε is a random disturbance term (26).

The structural equation model is based on a regression model to statistically analyze the latent variables and to verify whether the relationship between the latent variables is consistent with the reality. The structural equation consists of a measurement model and a structural model. Equations (2) to (4) are the measurement model and equation (5) is the structural model, and the relationships are as follows (27).

$$Spiritual_i = \Lambda_{Spiritual_i} X_1 + \delta_1 \quad (2)$$

$$Ability_i = \Lambda_{Ability_i} X_2 + \delta_2 \quad (3)$$

$$Health_i = \Lambda_{Health_i} X_3 + \varepsilon \quad (4)$$

$Spiritual_i$ represents access to the ith type of spiritual comfort type of senior service, $Ability_i$ represents access to the ith type of health care facilities, and $Health_i$ represents the ith type of mental health of older people. $Spiritual_i$ and $Ability_i$ are indicators of exogenous latent variables, $Health_i$ is an indicator of endogenous latent variables, $\Lambda_{Spiritual_i}$, $\Lambda_{Ability_i}$ denote the relationship between $Spiritual_i$, $Ability_i$ and X_i, respectively, Λ_{Health_i} denotes the relationship between $Health_i$ and

Y, and δ_i and ε are the errors on the measurement of latent variable indicators.

$$Y = \Gamma_i X_i + \varsigma \quad (5)$$

where Y denotes the endogenous latent variable, X_i denotes the exogenous latent variable, Γ_i denotes the effect of the ith exogenous latent variable on the endogenous latent variable, and ς denotes the part of the model that fails to be explained within the model.

Results

Mental health status of different older adults

The proportion of older women with poorer mental health is greater than that of older men, the older an older person is, the more fragile their mental health status becomes; in terms of household type, older adults in urban households have more optimistic mental health status than those in rural households. The mental health of older people who are divorced, widowed or unmarried is worse than that of those who have a partner. Older adults without pension insurance were more likely to be mentally unhealthy, and those with an annual household income of more than 60,000 yuan had better mental health than those with an annual household income of <10,000 yuan and those with an annual household income of 10,000 yuan to 60,000 yuan (Table 4). It is clear from this that as older adults age and lose their roles, widowhood, retirement, etc., older adults reduce their activity level and their contact with others, leading to a loss of social connections that can lead to psychological problems such as loneliness, anxiety, and depression.

TABLE 4 Basic mental health status of different older adults.

Variables		Mental health status (%)		χ^2	P-value
		Health	Vulnerability		
Individual characteristics	Age			255.47	<0.001
	60~69 year old	1,131 (73.78%)	402(26.22%)		
	70~79 year old	2,542 (71.09%)	1,034 (28.91%)		
	≥80 year old	4,357 (57.98%)	3,158 (42.02%)		
	Sex			189.00	<0.001
	Male	4,153 (70.80%)	1,713 (29.20%)		
	Female	3,877 (57.37%)	2,881 (42.63%)		
	Household type			79.58	<0.001
	Urban	2,545 (69.80%)	1,101 (30.20%)		
	Rural	5,485 (61.09%)	3,493 (38.91%)		
	Marital status			282.44	<0.001
	Married	4,229 (71.39%)	1,695 (28.61%)		
	Single	3,801 (56.73%)	2,899 (43.27%)		
Family status	Residence type			67.58	<0.001
	Living with family	6,612 (65.24%)	3,523 (34.76%)		
	Living alone	1,203 (57.64%)	884 (42.36%)		
	Senior care facilities	215(53.48%)	187 (46.52%)		
	Care by family and friends			17.59	<0.001
	Yes	8,394 (67.83%)	3,981 (32.17%)		
	No	137(55.24%)	111(44.76%)		
Lifestyle	Smoking or not			47.72	<0.001
	Yes	1,488 (71.37%)	597(28.63%)		
	No	6,542 (62.07%)	3,997 (37.93%)		
	Drinking or not			90.17	<0.001
	Yes	1,486 (74.30%)	514 (25.70%)		
	No	6,544 (61.60%)	4,080 (38.40%)		
	Whether to exercise			442.30	<0.001
	Yes	3,312 (75.56%)	1,071 (24.44%)		
	No	4,718 (57.25%)	3,523 (42.75%)		
Economic status	Pension insurance			73.08	<0.001
	Yes	3,347 (67.49%)	1,612 (32.51%)		
	No	4,683 (61.10%)	2,982 (38.90%)		
	Social security and commercial			57.6	<0.001
	Yes	198 (65.56%)	104 (34.44%)		
	No	8,333 (67.63%)	3,988 (32.37%)		
	Annual household income			249.77	<0.001
	Under 10,000 RMB	1,933 (59.62%)	1,309 (40.38%)		
	10,000 RMB-60,000 RMB	3,419 (68.48%)	1,574 (31.52%)		
	Over 60,000 RMB	3,179 (72.45%)	1,209 (27.55%)		

Regression results analysis of factors influencing mental health of older people

In this study, the independent variables that passed the chi-square test were placed in the regression model as the dependent variable of correlating, and the regression results are shown in Table 5. Emotional characteristics in the mental health of older people are significantly affected by the spiritual comfort services, however, the effects on geriatric depression, geriatric anxiety and cognitive impairment were not significant. Older adults who had access to spiritual comfort type of senior services had 90.5% of the risk of having negative emotional characteristics as those who did not have access. For the emotional characteristics of older adults, sex, type of household registration, care by family and friends, whether they drink alcohol, whether they exercise, pension insurance, social and commercial insurance, and annual household income had significant effects on emotional characteristics. The risk of negative mood among female older adults was 1.168 times higher than that of male older adults, the risk of negative mood among rural older adults was 1.385 times higher than that of urban older adults, the risk of negative mood among older adults who drank alcohol regularly and exercised regularly was 0.797 and 0.648 times higher than that of older adults who did not drink alcohol or exercise respectively, the risk of negative mood among older adults with pension insurance and social insurance was 0.811 and 0.648 times higher than that of older adults without insurance, respectively. The higher the annual household income, the lower the risk of negative emotion among older people. For depressive

TABLE 5 Regression results of mental health level of older people.

Variables		Emotional characteristics	Geriatric depression	Geriatric anxiety	Cognitive impairment
Spiritual comfort services		0.905***	0.993	1.026	1.049
Individual characteristics	Age (60~69 year old)				
	70~79 year old	0.979	1.078	0.863	1.641***
	≥80 year old	0.896	1.232**	0.875	6.133***
	Sex (male)				
	Female	1.168***	1.304***	1.706***	1.708***
	Household type (urban)				
	Rural	1.385***	1.109*	1.212	1.444**
	Marital status (married)				
	Single	1.071	0.860**	0.892	0.511***
Family status	Residence type (living with family)				
	Living alone	1.031	1.198***	0.910	0.599***
	Senior care facilities	1.226*	1.504***	0.909	1.294**
	Care by family and friends (No)				
	Yes	0.742*	0.487***	0.172***	1.129
Lifestyle	Smoking or not (No)				
	Yes	0.936	0.953	0.511**	0.995
	Drinking or not (No)				
	Yes	0.797***	0.759***	0.949	0.871*
	Whether to exercise (No)				
	Yes	0.648***	0.519***	0.549***	0.656***
Economic status	Pension insurance (No)				
	Yes	0.811***	0.841***	1.091	1.171***
	Social security and commercial (no)				
	Yes	0.686***	0.871	0.979	1.137
	Annual household income (under 10,000 RMB)				
	10,000 RMB-60,000 RMB	0.818***	0.707***	0.647**	0.797***
	Over 60000RMB	0.706***	0.698***	0.596**	0.695***
	N	12,624	12,624	12,624	12,624

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. The values in the table are OR values.

symptoms in older adults, age, sex, type of household registration, marital status, residence type, care by family and friends, whether or not they drink alcohol, whether or not they exercise, pension insurance, social and commercial insurance, and annual household income had a significant effect on depression in older adults. The risk of depression was 1.304 times higher among female seniors than male seniors, 1.198 and 1.504 times higher among older people living alone or in a nursing facility than among older people living with family members, respectively, 0.487 times higher among older people being cared for by friends and relatives than among older people not being cared for by friends and relatives. The risk of depression among older people who drink alcohol and exercise regularly is 0.759 and 0.519 times higher than that of older people who do not drink alcohol or exercise, respectively, and the risk of depression among older people who have pension insurance is 0.841 times higher than that of older people who do not have insurance. The higher the annual household income, the lower the risk of depression in older adults. For anxiety symptoms in older adults, sex, care by family and friends, whether or not they smoked, whether or not they exercised, and annual household income had significant effects on anxiety in older adults. The risk of anxiety in female seniors was 1.706 times higher than that in male seniors, the risk of anxiety among older people who were cared for by family and friends was 0.172 times higher than that among older people who were not cared for by family and friends, the risk of anxiety among older people who smoked regularly and exercised regularly was 0.511 and 0.549 times higher than that among older people who did not smoke or exercise, respectively, and the higher the annual household income, the lower the risk of anxiety in older people. For cognitive impairment in older adults, age, sex, household type, marital status, residence type, whether or not they drink alcohol, whether or not they exercise, pension insurance, and annual household income had significant effects on cognitive impairment. The risk of cognitive impairment was higher for older adults, 1.708 times higher for female than male

adults, lower for single than married adults, lower for those living alone, and higher for those living in a nursing facility, the risk of cognitive impairment was 0.656 times higher in older adults who exercised regularly than in those who did not, and the risk of cognitive impairment was greater in those with pension insurance. The higher the annual household income, the lower the risk of cognitive impairment in older adults.

Mechanism of the role of spiritual comfort services and health care facilities in influencing mental health of older people

The model fit test was first conducted, and the results showed that the model fit was ideal with $\chi^2/df = 19.079$, GFI = 0.987, AGF = 0.980, and RMSEA = 0.038. Figure 3 reports the standardized coefficients of the structural equation model, and the results show that the standardized regression coefficients of the spiritual comfort services on the health care facilities of older people are significant and positive, and the standardized regression coefficients of the health care faclities on the mental health are negative. This shows that spiritual comfort services can alleviate negative psychological emotions such as anxiety and depression of older people by influencing their health care facilities.

According to the mental health mechanism and research framework of older people, the relationship between the three latent variables was verified in this study, and the parameters were estimated by the maximum likelihood method, and the structural model estimation results are shown in Table 6. Specifically, the regression coefficient of spiritual comfort services on health care facilities was significantly positive, implying that spiritual comfort services may enhance the health care facilities of older people, which in turn may have some impact on their mental health; meanwhile, the regression coefficient of health care facilities on the
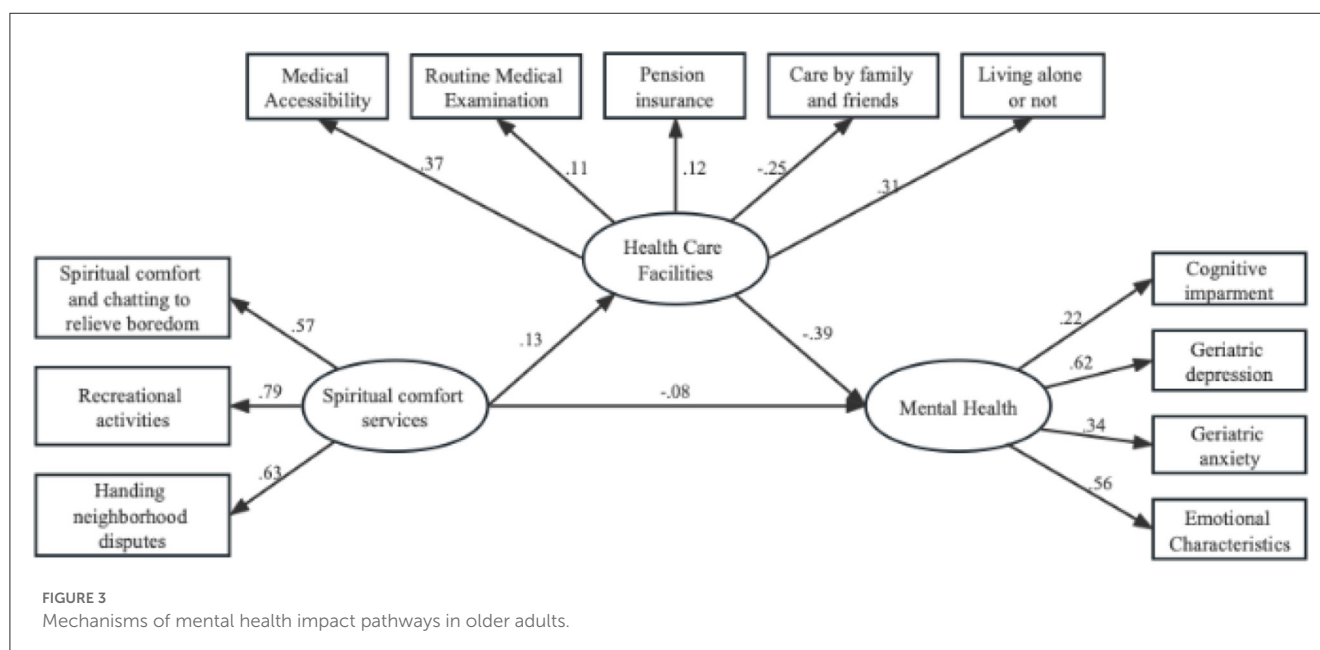

FIGURE 3
Mechanisms of mental health impact pathways in older adults.

TABLE 6 Structural equation model estimation results.

Paths	Estimate	SE	CR	P-value
Spiritual comfort services → Mental health	−0.076	0.020	−4.772	P<0.001
Health care facilities → Mental health	−0.394	0.050	−9.632	P<0.001
Mental comfort services → Health Care Facilities	0.128	0.028	6.112	P<0.001

The standard coefficients are reported in the table.

mental health of older people is significantly negative, indicating that the mental health condition of older people who lack health care facilities will be more serious, and mental health status of older adults deteriorates as health care becomes weaker. The regression coefficient of the spiritual comfort services on the psychological health of older people was significantly negative, indicating that the spiritual comfort services directly affected the psychological health of older people. There were significant correlations between the three latent variables and the corresponding observed variables, and each 1-unit increase in the service for dealing with neighborhood disputes, the service for recreational activities, and the service for spiritual comfort and chatting to relieve boredom increased the mental health of the older adults by 0.630, 0.791, and 0.572, respectively, as shown by the results of the measurement model estimation (Table 7). Community spiritual comfort services help older people to give them social support in their familiar environment and without severing their original social network, so that they can more easily gain a sense of belonging and security, alleviate the negative psychology brought about by a sense of uselessness and frustration, thus maintaining a positive psychological mood and a healthy mindset in life, and improve their physical and mental health. It is noteworthy that the significant coefficient of the observed variable whether the potential variable health care facilities corresponds to living alone is negative, revealing that older people living alone do not live with their own relatives and children, lack communication with their children, and may experience loneliness, depression, spiritual emptiness, lack of solace, and also more likely to lack a sense of security and belonging.

Analysis of the role of intermediaries

This study explored the mediating effect between spiritual comfort services and the mental health of older people through health care facilities, using Bootstrap confidence interval estimation method for interval estimation, selecting 95% confidence interval and repeating 5,000 times to test the mediating effect between spiritual comfort services and the mental health of older people, the direct, indirect and total effects of spiritual comfort type of senior services on the mental health of older people are shown in Table 8.

As can be seen in Table 8, the total effect in the path from spiritual comfort services to mental health is −0.127, the direct effect is −0.076, and the indirect effect is −0.051, and the results are all significant at the 0.05 level of significance, indicating that there is a significant effect of the provision of spiritual comfort services on the mental health of older people, and there is a partial mediating

effect; indicating that spiritual comfort services indirectly affects mental health by influencing the health care facilities of older people; it confirms that the spiritual comfort services mainly has an effect through the health care facilities mediating variable, and the health care facilities significantly improves the mental health of older people and has a mitigating and inhibiting effect on their mental health vulnerability.

Discussion

This study analyzed the mental health status of older adults and related influencing factors in China based on the CLHLS 2018 national survey data, which showed that the individual characteristics, family status, lifestyle and economic status of older adults were related to the mental health status of older adults, and the regression results revealed that sex, age, type of household, residence type, drink or not, whether to exercise, pension insurance, and annual household income were the most important factors influencing the mental health status of older adults, which was consistent with the results of existing studies (28). As the senior age, their physical functions gradually decline, thus cognitive functions are easily impaired, female seniors have deviations in mental health compared to male seniors, rural seniors have greater differences in living environment and living conditions compared to urban seniors, have single daily activities and less exposure to information (29), and are at greater risk of declining mental health levels, the lack of life care and emotional communication from spouses or children for older adults living alone or in institutions increases the risk of anxiety and depression. Participation in social activities and exercise can improve the physical health of older people, while maintaining social connections and avoiding social isolation, so that the risk of depression and anxiety decreases and social integration of older people is promoted.

The results of Bootstrap method proved that health care facilities has a partial mediating effect in the mental health status of older people with the ratio of mediating effect to total effect of 40.16%, indicating that the effect of spiritual comfort services on the mental health of older people may be effected through health care facilities.

Previous studies have shown that loss of health care facilities in older adults such as lack of social support, social isolation, and poor family relationships is associated with increased mortality, poorer self-rated health, lower quality of life, and higher risk of dementia (30, 31). It can also have profound negative effects on the health of older adults, such as psychological vulnerability (decreased cognitive, emotional, and coping abilities) and social vulnerability (decreased social relationships and social support), while older people with poor health and physical dysfunction are also more likely to feel lonely as well as more sensitive and dependent on the resources of their surroundings, thus affecting the wellbeing of older individuals. In older age groups, older adults with more social relationships and social involvement have better mental health status and physical health (32), which can improve their family relationships and social support to alleviate depressive symptoms in older patients. Consistent with the results of this study, by promoting the health care facilities of older adults, thus

TABLE 7 Measurement model estimation results.

Potential variables	Observed variables	Estimate	SE	CR	P-value
Spiritual comfort services	Handing neighborhood disputes	0.630	0.009	-	P<0.001
	Recreational activities	0.791	0.010	44.561	P<0.001
	Spiritual comfort and chatting to relieve boredom	0.572	0.011	47.059	P<0.001
Health care facilities	Medical accessibility	0.369	0.035	-	P<0.001
	Routine medical examination	0.106	0.022	6.159	P<0.001
	Pension insurance	0.116	0.024	6.662	P<0.001
	Care by family and friends	0.307	0.048	11.546	P<0.001
	Living alone or not	−0.249	0.032	−10.894	P<0.001
Mental health	Cognitive impairment	0.224	0.013	-	P<0.001
	Geriatric depression	0.619	0.015	17.063	P<0.001
	Geriatric anxiety	0.339	0.017	15.910	P<0.001
	Emotional characteristics	0.555	0.015	17.286	P<0.001

The standard coefficients are reported in the table.

TABLE 8 Bootstrap model test results.

Effect	Paths	Estimate	Bias-corrected percentile Bootstrap	
			95%CI LI	95%CI UI
Total effect	Spiritual comfort services→ Mental health	−0.127***	−0.152	−0.100
Direct effect	Spiritual comfort services→ Mental health	−0.076**	−0.111	−0.032
Indirect effect	Spiritual comfort services→ Mental health	−0.051***	−0.094	−0.028

*P < 0.05, **P < 0.01, ***P < 0.001.

inhibiting or slowing down the generation of negative psychological emotions and improving their physical and mental health.

The use of spiritual comfort services can improve the mental health of older adults, effectively reducing and alleviating their mental health maladies, while better addressing the medical, psychological, cognitive and social needs of older adults and other patients with serious illnesses. Some studies have shown that spiritual comfort services not only improve the mental health of older people and effectively alleviate the feelings of loneliness and anxiety that occur in old age, but also improve the quality of life as well as the subjective perception level of older people (33). It is also believed that helping older people to eliminate the distress and anxiety in their hearts by communicating with them can alleviate their negative emotions such as loneliness and depression (34), which can play a positive spiritual and psychological role especially for the empty nesters or those whose children are unable to provide home care for older people due to their busy work schedules.

Moreover, the content of the spiritual comfort services should match the spiritual needs of older people, and when the community senior care needs are responded to, the utility of older people will be improved, thus satisfying their multi-level diversified needs in physical, psychological and cognitive aspects and improving the ability of older people to resist physical and mental health vulnerability (35). The community is an important guarantee for older people to enjoy socialized senior services, and the supply of community-based spiritual comfort services may be an important

way to improve the mental health of older people, delay the trend of declining self-care ability of older people, and increase the effectiveness of socialized senior services (36). This finding suggests that community-based spiritual services are a key social factor influencing the mental health of older adults, as well as alleviating the stress of family caregiving and being an effective measure to address the health problems of older adults and improve their quality of life.

Based on the above research findings, the study makes some policy recommendations. We should carry out "mental health screening" for older people and rely on the community platform for accurate management. On the basis of the mental health assessment of older people, the service items, contents and standards are reasonably determined. To develop specific care and nursing intervention programs for the mentally unhealthy older people, including early determination of the degree of unhealthiness, timely assessment and active treatment, health education for older people, and design of more effective preventive measures for psychological intervention, social support and self-care ability. Orienting on the actual needs of older people, focusing on older people who are unable to take care of themselves, achieving a precise match between service supply and the needs of older people, focusing on disease prevention and management, active aging and social participation, etc., focusing on guiding older people to establish a positive view of aging, and making policy interventions in terms of improving the accessibility of medical care and the level of informal support for older people.

Limitations

This study has the following limitations: first, there is a lack of period differences and age differences in the effects of mental comfort-type senior services on the mental health of older people; second, in reality, the mental health status of older people is the result of a combination of multiple influencing factors, and a more convincing indicator system is needed to measure the mental health of older people; third, because this study uses secondary data for analysis, it is limited by the variables of primary data, and only studies the differences at the individual level, and lacks the differential effects between different regions, different economic conditions and different living standards.

Conclusion

In conclusion, this study uses cross-sectional data and structural equation modeling to examine the impact of spiritual comfort services in a community setting on the level of mental health of older adults and its impact on effectively reducing and mitigating their mental health vulnerability while better addressing the medical, psychological, cognitive, and social needs of older adults and other patients with serious illnesses.

Communities should optimize spiritual comfort services to maximize the effect of alleviating poor mental health and improving mental health by preventing or delaying the progress of poor mental health, so as to improve the physical and mental health of older people, improve the quality of life and mental health of older people, and promote healthy aging.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://opendata.pku.edu.cn/dataset.xhtml?persistentId=doi:10.18170/DVN/WBO7LK.

Ethics statement

The studies involving human participants were reviewed and approved by Medical Ethics Committee of Yunnan First People's Hospital. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

JD conducted field survey, collected data, provided suggestions, and manuscript preparation. YL conducted data collection, intervention, statistical analysis and manuscript design, writing, and editing. XZ conducted field survey, advised, conceived, and designed the work and edited the final version of the manuscript. ZW analyzed data and drew figures. YY provided suggestions, assisted in an English manuscript, and edited the manuscript. JD, YL, and XZ have full access to all the data in this study and takes primary responsibility for the final content. All authors have read and approved the final version of the manuscript.

Conflict of interest

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

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Social isolation and intrinsic capacity among left-behind older adults in rural China: The chain mediating effect of perceived stress and health-promoting behavior

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Background: Strengthening and maintaining the intrinsic capacity (IC) of the older adults is the key to preventing and delaying disability and promoting healthy aging.

Objective: This study explores the relationship between social isolation, perceived stress, health promotion behavior, and IC of the left-behind older adults in rural areas and analyzes the chain mediating effect of perceived stress and health promotion behavior among social isolation and IC.

Methods: From March 2021 to May 2022, a multi-stage sampling method was used to recruit participants from rural areas in Heilongjiang Province, China. The data were collected by the simplified version of the Lubben Social Network Scale, the Chinese Perceived Stress Scale, the Health-Promoting Lifestyle Profile-Chinese, and the Integrated Care for Older People (ICOPE) screening tool. We used the PROCESS macro for SPSS to determine the mediating effect of perceived stress and health-promoting behavior between social isolation and IC.

Result: Social isolation score was positively correlated with health-promoting behavior ($r = 0.78$, $p < 0.01$) and IC ($r = 0.67$, $p < 0.01$), whereas it was negatively correlated with perceived stress ($r = -0.63$, $p < 0.01$). Perceived stress was negatively correlated with health-promoting behavior ($r = -0.62$, $p < 0.01$) and IC ($r = -0.43$, $p < 0.01$). The health-promoting behavior and IC were positively correlated ($r = 0.56$, $p < 0.01$). Bootstrapping values indicated that the chain-mediating effect of perceived stress and health-promoting behavior was statistically significant.

Conclusion: Consequently, to improve the IC of the left-behind older adults, we should focus more on reducing the degree of social isolation of the left-behind older adults and improving their perceived stress and health-promoting behavior.

KEYWORDS

left-behind elderly, social isolation, perceived stress, health-promoting behavior, intrinsic capacity

1. Introduction

By the end of 2016, there were around 240 million people over 60 years, accounting for 16.7 percent of the total population. The left-behind older adults accounted for 25.8% of the elder adults. It can be inferred that by the end of 2016, the population of the left-behind older adults in China was 59.88188 million (1, 2). The National Working Committee on Aging predicts that by 2030, there will be >200 million left-behind older adults people in rural areas (3). The left-behind older adults in rural areas refers to those with rural household registration, aged above 60, whose children under the same household registration go out for work for more than 6 months each year, and who have no one to support them (4). Human organ and tissue functions, as well as physical abilities, gradually decline with age. Some older people might also have impaired daily activities and even lose the ability to live independently. China's disabled and semi-disabled older adults had reached 40 million by the end of 2019, with rural disabled and semi-disabled older adults accounting for 64.5% (5). Based on this, it is inferred that nearly 10 million of the left-behind older adults are disabled. Due to the lack of family care capacity for children working outside, the limited economic capacity of rural families, and the insufficient supply of social services at home, providing disability care for the older adults left behind in rural areas face many challenges. Therefore, preventing the disability of rural left-behind older people is significant for reducing the burden of family care and realizing healthy aging.

Strengthening and maintaining the intrinsic capacity (IC) of the older adults is the key to preventing and delaying disability and promoting healthy aging. IC is a combination of all the physical and mental strength that an individual can use at any time and includes five areas: cognition, psychology, sensory function, vitality, and activity, which reflect the overall health status of the older adults (6). The decline in IC is common in the community and among hospitalized older people. Based on the National Population Representative Sample Survey results, the overall incidence of IC decline was 43%. The prevalence rate of IC decline in the rural older adults was 1.36 times higher than that of the urban older adults population ($p < 0.001$) (7). It has also been observed that older people living in rural areas have a higher rate of IC decline. According to the Convoy Model of Social Relations, the scale, quality, and function of an individual's social relationships change over time and play an important role in the mental and physical health of the older adults (8). For the left-behind older adults in rural areas, maintaining proper living conditions is extremely difficult. As they have very limited sources of income, they usually undertake heavy agricultural labor or "intergenerational education." They sometimes may even encounter the double exclusion of material and spiritual support, thus, showing a state of "social isolation." In a state of lack of social resources, social isolation can easily lead to a variety of adverse health outcomes for the older adults, which can significantly reduce their physical status, cognitive function, and mental health level, lead to declined IC, and increase their readmission as well as mortality rates. Social isolation can have serious effects on the quality of life and safety of the older adults (9).

Perceived stress refers to the process of perceptual evaluation of stress, i.e., individuals make an integrated assessment of external stressful events through the perceptual process involving three stages of perception: perceptual organization, judgment, and recognition (10). Several studies have shown that social isolation can indirectly affect the cognition, emotion, and physical activities of the older adults through perceived stress, leading to a decline in IC (11, 12). Yang et al. (10) examined the perception mechanism more precisely, i.e., after being stimulated by threatening events and negative factors in life, the psychological changes after subjective cognitive system evaluation usually showed symptoms of tension and out-of-control. Furthermore, it can potentially harm the individual's physiology, emotion, cognition, and behavior, which is a high-risk factor leading to a lower IC (13). It is suggested that social isolation can also lead to an increase in perceived stress, leading to a decline in IC.

Health-promoting behavior is a series of methods or actions that can improve an individual's health, such as physical exercise and stress management behavior. The emergence of social isolation may hinder the older adults from obtaining social support from available social networks and establishing health awareness, thus, affecting their health-promoting behavior, leading to less physical activity, anxiety, depression and decline in cognitive functions, weakening the IC of the rural left-behind older adults (14, 15). The main effect model emphasizes that good social relations positively impact an individual's health (16). Social network support can effectively regulate individual behavior and enhance the sense of control over one's life to maintain good health. Li et al. found that a high level of stress perception can hinder their health promotion behavior ability; the higher the perceived stress level, the lower the health promotion behavior ability (17).

However, there are few existing studies on the older adults left behind in rural areas to support this hypothesis. According to the main effect model, the relationship between social network relationships and overall health is established primarily through two mechanisms: first, the emotional support function of social support can effectively adjust the individual stress coping level and enhance the individual's ability to resist diseases, thereby maintaining overall health. Second, social network support can effectively regulate individual behavior and form more healthy behavior. The main effect model provides a theoretical basis for the psycho-behavioral path of social isolation on internal ability decline reported in this study (18). Therefore, this study aimed to explore the relationship and the mechanism of social isolation, perceived stress, health-promoting behavior, and intrinsic capacity in left-behind older adults in rural China, as these parameters play an important role in improving the IC and quality of life. This research proposes four hypotheses: (H1) Social isolation is related to IC; (H2) Perceived stress may play a mediating role between social isolation and IC; (H3) Health-promoting behavior may show a mediating function in social isolation and IC; and (H4) Perceived stress and health-promoting behavior may have a chain mediating effect between social isolation and IC.

TABLE 1 Characteristics of the study population.

Characteristics	Variables	N	%
Gender	Female	200	54.6%
	Gender	166	45.4%
Age	60–70	163	44.5%
	70–80	150	41.0%
	>80	53	14.5%
Education level	Primary school and below	186	50.8%
	Secondary school	138	37.7%
	High school or above	42	11.5%
Marital status	Married	267	73.0%
	Single (never married, divorced, separated and widowed)	99	17.0%
Household monthly income	Low (≤1,000 rmb)	184	50.3%
	Middle (1,000–3,000 rmb)	132	36.1%
	High (>3,000 rmb)	50	13.6%
Social isolation	Family isolation	147	40.8%
	Friend isolation	70	19.4%
Self-reported perceived health status	Very poor	22	6.0%
	Poor	118	32.2%
	Fair	140	38.3%
	Good	77	21.0%
	Very good	9	2.5%

2. Materials and methods

2.1. Participants

We chose Heilongjiang Province as the research site because it is located in northern China, in the cold circle of Siberian high pressure. Since winters are too cold and long to grow food, most young and middle-aged people go elsewhere to go work, leaving the older adults at home alone. And due to budgetary and time constraints, a nationwide survey could not be implemented, and we have mentioned this as a limitation in the discussion section. As this was a cross-sectional study, it used the multi-stage sampling method from March 2021 to May 2022, according to the 2020 GDP ranking of Heilongjiang Province, that displayed the division of economic levels of 13 regions in Heilongjiang Province into three squares: high, medium and low. In a cross-sectional study, the sample size was calculated using the random sample size formula: $n = u_{\alpha/2}^2 \pi (1-\pi)/\delta^2$, n: estimated sample size; π: population rate, according to the literature review, social isolation accounted for 25% of the total older adults population ([19]); $u_{\alpha/2}$: the value corresponding to 95% confidence interval under the normal distribution curve, $u_{\alpha/2}$= 1.96, δ: allowable error. The maximum allowable error in this study was set at 5%. The sample size of the urban and rural surveys was determined to be 350 cases based on the non-response rate of 15% and to ensure the stability of the path model. In the first stage, researchers randomly selected three cities (Daqing, Jixi, and Qitaihe) from Heilongjiang Province based on their economic development. In the second stage, one township was randomly selected from each selected city, whereas in the third stage, two or three natural villages were randomly selected from each selected township. The cluster sampling method was used, and the older adults in all selected villages were included as study subjects. The inclusion criteria were as follows: (1) local permanent residents (registered in rural areas), (2) age ≥ 60 years old, (3) offspring who had been working outside for >6 months every year, (4) participants having clear consciousness and normal communication with investigators, and (5) participants providing informed consent and voluntary participation. We excluded all participants suffering from poor attention and listening skills, other sensory disorders, and serious mental and physical ailments.

2.2. Data collection

All participants were recruited from the wards after getting approval from the Ethics Committee of Harbin Medical University Daqing Campus. Data were collected through face-to-face interviews. First, the researchers explained the purpose of the study to all eligible participants, and those who agreed to take part signed a written informed consent form. The researchers explained the standardized instructions to all participants during the data collection process, and they then completed the questionnaire on their own. Each older adult completed the questionnaire in

TABLE 2 Statistical description and related analysis results.

	M	SD	1	2	3	4
1	20.26	3.30	1			
2	24.44	3.60	−0.63**	1		
3	103.77	21.18	0.77**	−0.62**	1	
4	5.49	1.53	0.68**	−0.54**	0.61**	1

1 = social isolation; 2 = perceived stress; 3 = health promoting behavior; 4 = intrinsic capacity. **$P < 0.01$.

30~40 min. The researchers clarified all points and concerns raised by the participants. In cases of incomplete self-filled questionnaires, the researcher read each questionnaire item and recorded their responses. All questionnaires are collected on the spot and checked for completion. Based on the inclusion rate, a total of 392 questionnaires were distributed in this survey, and 366 valid questionnaires were recovered, the response rate is 93.4%.

2.3. Measures

2.3.1. The general information

General characteristics such as gender, age, education, marital status, monthly family income, and self-assessed health status that may have an impact on the IC in left-behind older adults in rural China were included based on a review of the literature.

2.3.2. Social isolation

The simplified version of the Lubben Social Network Scale (LSNS), developed by Lubben, was used to assess social isolation (20). The scale included six items, further divided into two dimensions: family network and friend network. Each item was scored by a 6-point Likert scale (0–5), while the total scoring was done from 0 to 30. A score of <12 indicated that the older adults were socially isolated. Furthermore, while scoring for family and friend networks, each dimension of the questionnaire <6 points indicated family isolation and friend isolation, with a lower score suggesting a higher risk of social isolation. The Cronbach's α of the LSNS in this study was 0.794.

2.3.3. Perceived stress

The Chinese Perceived Stress Scale (CPSS) used to assess perceived stress was developed by Cohen et al. (21) and translated by Yang and Huang (10). The scale consisted of 14 items, including two dimensions of tension and out of control. Using the Likert 5-grade scoring method, the score range was 0–56. The higher the score, the greater the psychological pressure perceived by the subjects. The Cronbach's α of the CPSS in this study was 0.847.

2.3.4. Health-promoting behavior

Health-promoting behavior was measured by the Health-Promoting Lifestyle Profile-Chinese (HPLP-C). It was developed by Walker and translated by Chen. It included 40 items on a 4-point scale across six dimensions: nutrition behavior, health responsibility behavior, self-actualization behavior, social support behavior, exercise behavior, and stress management behavior (22, 23). The total score ranged from 40 to 160 points, with higher scores indicating a higher health-promoting behavior. The Cronbach's α of the HPLP-C in this study was 0.953.

2.3.5. Intrinsic capacity

The assessment of IC was based on the WHO-published Integrated Care for Older People (ICOPE) screening tool (24), including the Mini-Mental State Examination (MMSE) (25), Short Physical Performance Battery Test (SPPB) (26), Mini-Nutritional Assessment Short Form (MNA-SF) (27), and Geriatric Depression Scale-15 (GDS-15) (28) and included following evaluations: (1) Cognition: two items about orientation and memory were spared from MMSE. (2) Locomotion: chair rise test assessed one part of the SPPB. (3) Vitality: weight loss and appetite loss were recorded according to MNA-SF. (4) Sensory: vision and hearing loss were measured using self-reported and validated questions. (5) Psychosocial: depressive symptoms were evaluated using two questions from the GDS-15. ICOPE screening tool contained nine dichotomous questions that were coded as 1 or 0. We derived a summary of IC scores by adding all the responses to nine dichotomous questions from five domains (possible range: 0–9). The higher the score, the better the capacity. The Cronbach's α of the CPSS in this study was 0.912.

2.4. Statistical analyses

SPSS22.0 statistical software was used for statistical analysis, including descriptive analysis, reliability coefficient, and Pearson's correlation analysis. Harman's single factor test was used to check the common method deviation of all the variables; Model 6 in the Hayes' SPSS PROCESS v3.5 macro program was used to analyze the mediating effect. A non-parametric Bootstrap method was used by re-sampling 5,000 times to verify the significance of the intermediary effect of perceived stress and health behavior in social isolation and IC.

3. Results

3.1. Common method deviation test

Harman's single-factor test was used to include all variables in this study in exploratory factor analysis. The results revealed that a total of 12 factors had characteristic roots >1. In contrast, the variation explanation rate of the first factor was 18.90%, which was less than the critical standard of 40%, indicating that there was no obvious common method bias problem in the study data.

3.2. Characteristics of the study population

A total of 366 rural left-behind older adults were included in this study, consisting of 166 males (45.4%) and 200 females (54.6%).

TABLE 3 Regression analysis among variables in the chain intermediary model.

Outcome variable	Predictor variable	R	R²	F	β	T
Perceived stress	Social isolation	0.63	0.40	244.3**	−0.63	−15.63**
Health promoting behavior	Social isolation	0.79	0.63	304.40**	0.61	14.92**
	Perceived stress				−0.23	−5.74**
Intrinsic capacity	Social isolation	0.70	0.49	117.43**	0.47	7.57**
	Perceived stress				−0.15	−2.98**
	Health promoting behavior				0.16	2.54*

*$P < 0.05$, **$P < 0.01$.

TABLE 4 Analysis of the mediating effect of perceived stress and health promoting behavior.

	Effect size	Standard error	Boot CI LL	Boot CI UL
Direct effect	0.465	0.061	0.000	0.344
Indirect effect 1	0.095	0.035	0.028	0.166
Indirect effect 2	0.096	0.038	0.021	0.170
Indirect effect 3	0.024	0.010	0.005	0.045
Total mediation effect	0.215	0.050	0.120	0.313

Indirect effect 1: social isolation→ perceived stress→ IC. Indirect effect 2: social isolation→ health promoting behavior→ IC. Indirect effect 3: social isolation→ perceived stress→ health promoting behavior→ IC.

Although the age ranged from 60 to 86 (71.0 ± 6.17) years old, the education level was mainly primary school or below. 40.8 and 19.4% of left-behind older people were isolated by family and friends, respectively, as shown in Table 1.

3.3. Relationship between social isolation, perceived stress, health-promoting behavior, and intrinsic capacity

In this study, the Lubben Social Network Scale was used to evaluate the social isolation level of the older adults. The lower the questionnaire score, the more serious the social isolation level. Social isolation was positively correlated with health-promoting behavior ($r = 0.78$, $p < 0.01$) and IC ($r = 0.67$, $p < 0.01$), whereas social isolation was negatively correlated with perceived stress ($r = −0.63$, $p < 0.01$). Perceived stress was negatively correlated with health-promoting behavior ($r = −0.62$, $p < 0.01$) and IC ($r = −0.43$, $p < 0.01$). Finally, there was a correlation between health-promoting behavior and IC ($r = 0.56$, $p < 0.01$, Table 2). It offers preliminary support for further research into the hypothesis.

3.4. The mediation of perceived stress and health-promoting behavior in the relationship between social isolation and intrinsic capacity

According to Haye's SPSS macro program PROCESS, model 6 was used for regression analysis. The results showed that social

isolation could significantly predict IC ($β = 0.47$, $p < 0.01$). Social isolation had a significant negative prediction of perceived stress ($β = −0.63$, $p < 0.01$) and a significant positive prediction of health-promoting behavior ($β = 0.61$, $p < 0.01$). Perceived stress had a significant negative predictive effect on the health-promoting behavior ($β = −0.23$, $p < 0.01$) and a significant negative predictive effect on IC ($β = −0.15$, $p < 0.01$). Finally, the health-promoting behavior positively predicted IC ($β = 0.16$, $p < 0.05$, Table 3). The preliminary judgment based on the structural equation model was that a perceived stress and health-promoting behavior mediation path existed, but the mediation effect (path coefficient of the product) required further verification. The non-parametric percentile bootstrap method was used to assess the mediation effect further. The results showed that the 95% CI corresponding to each path did not contain 0, which indicated the significance of the mediation effect, and established the chain mediation (Table 4). In line with our hypotheses, our results suggest that perceived stress and health-promoting behavior mediate the relationships between social isolation and intrinsic capacity. Figure 1 shows that social isolation affects intrinsic capacity directly among rural older adults; perceived stress affects intrinsic capacity directly among rural older adults; health promoting behavior affects intrinsic capacity directly among rural older adults; perceived stress and health-promoting behavior have a chain mediating effect between social isolation and IC.
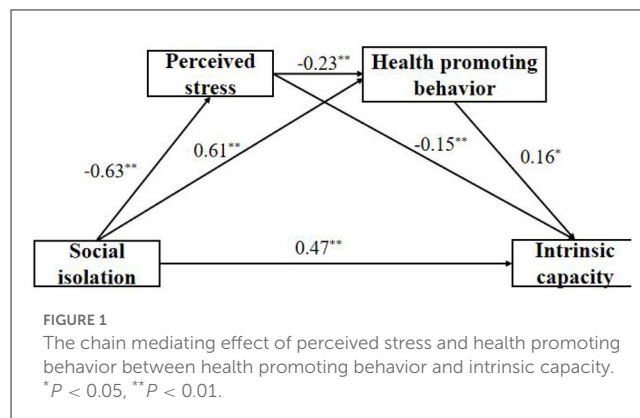
4. Discussion

The Cronbach's α of all questionnaires in this study ranged from 0.79 to 0.95, suggesting the ability to correctly identify the social and psychological characteristics of the older adults well. This

study discovered a link between social isolation and IC. We assess social isolation using the Lubben Social Network Scale, so the lower the social isolation score, the greater the social isolation. Social isolation, as a state of loss of social network, is prone to a variety of adverse health outcomes in the older adults. These outcomes can significantly affect their cognitive, psychological, and physical activities, reduce their overall health level (intrinsic ability), and increase their readmissions and mortality (9). So the community service workers can understand the social network characteristics of the rural older adults and provide targeted services. For example, cultural and recreational activities should be provided to encourage the older adults to participate actively and make up for the loss of social connection caused by aging as much as possible.

In line with our hypotheses, our results suggest that perceived stress played a part in the mediating role between social isolation and IC in left-behind older adults in rural China. Because of a lack of interaction and contact with their children and family, social support, as well as physical and spiritual resources, the older adults in rural areas face multiple pressures, such as physiological degradation and psychological crisis. They are sensitive and paranoid about their environment, and their constant preoccupation with their health adds to the source of stress, which increases their perceived stress level. The "stress increase hypothesis" depicted that social isolation itself is a source of stress, triggering an inflammatory cascade of events, thereby weakening the IC of the left-behind older adults and leading to a variety of psychological and physical ailments (29). However, when an individual encounters setbacks and stress, it does not necessarily directly affect the individual itself; the induced perceived stress can produce a series of emotional and behavioral responses. The stress buffer mechanism exhibited that social networks effectively reduce individuals' negative responses to stressful events by affecting individuals' subjective evaluation of stress (30). The failure to relieve them in these stressful times can lead to a series of physiological, biochemical, and immune system changes, affecting the cognition, emotion, and physical activities of the older adults and leading to a declined IC (11, 12).

This study showed that health-promoting behavior partially mediated between social isolation and IC, which was consistent with previous study results (31). The social network, as an important environmental factor, significantly influences the health-promoting behavior of the older adults. The larger an individual's social network, and the closer their connection with social members, the easier it is to obtain some health-related information. The more they can regulate their behavior to promote health (32). A study by Robins et al. (15) showed that individual health promotion behavior is one of the direct factors in improving health outcomes. The older adults left behind in rural areas often suffer social isolation due to reduced social networking (15). The emergence of social isolation may also hinder the older adults from obtaining social support from social networks, and establishing health awareness, thus, affecting their health-promoting behavior and leading to adverse health outcomes. Lu et al. (33) showed that the health promotion of the older adults could promote the physical activity ability and the cognitive level of IC by encouraging good health behavior, such as weight control and moderate physical exercise. Therefore, it is of great practical significance to further

FIGURE 1
The chain mediating effect of perceived stress and health promoting behavior between health promoting behavior and intrinsic capacity. $^*P < 0.05$, $^{**}P < 0.01$.

improve the social network relationships of the left-behind older adults in rural areas, to improve their health behavior and the IC of the older adults, thus, preventing disability.

Finally, the social isolation level of left-behind older adults can also affect IC through the chain mediating effect of perceived stress and health-promoting behavior. Our study results supported the findings of Li et al. (17), i.e., perceived stress can affect healthy behavior. Stress levels are more closely related to emotional eating, eating control smoking, and drinking behaviors, while perceived stress is negatively related to health-promotion behavior (34). When an individual is stressed for a long time, the brain increases the individual's burden through "allostatic load," which leads to systemic and functional insufficiency and initiates a series of adverse symptoms such as memory impairment, decreased concentration, and insomnia (8). It also affects the attention level toward an individual's health state and physical abilities, leading to a low healthy behavior ability. Perceived stress is one's own perception of external pressure, which is closely associated with poor physical and mental health. Social isolation can be regarded as a major risk factor that has been linked with increased awareness of stress among the left-behind older adults. Socially-induced stress affects the individuals' physiology, emotion, cognition, and mental behavior through the interplay of the nervous and endocrine systems. It can cause potential harm and a decline in their IC (35). As left-behind older adults in rural areas have been socially isolated for a long time, their social skills become poor, resulting in a lack of confidence while dealing with problems, eventually leading to a sense of tension and loss of control. Therefore, effective perceived stress management induces positive effects on IC. In contrast, the perceived stress management of rural left-behind older adults provides a new management path for the early prevention and treatment of disability.

Our research had some limitations. At first, while the mediation model was theoretically based, the cross-sectional study cannot fully infer the causal relationship between the variables. The use of longitudinal data in future studies could help to further investigate the conclusions of this study. Second, our study samples were all drawn from rural areas of Heilongjiang Province, limiting the generalizability of our findings. The diversity of the sample sources should be expanded in future studies. Thirdly, smaller samples cannot reflect the relationship between social isolation, perceived stress, health-promoting behavior, and intrinsic capacity

to a greater extent. Because of the aforementioned limitations, the analysis of the results in our study should be reviewed cautiously.

5. Conclusion

The findings of the present study suggest that social isolation can directly affect intrinsic capacity and that perceived stress and health-promoting behavior mediate the relationship between social isolation and intrinsic capacity in left-behind older adults in rural China. This study's findings also add to the body of evidence highlighting the significant effects of social isolation on an individual's intrinsic capacity.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: if necessary, data can be shared with the consent of the corresponding author. Requests to access these datasets should be directed to hltg210922@163.com.

Ethics statement

The studies involving human participants were reviewed and approved by Harbin Medical University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

HS: conception and design of the study, drafting the article, and approval of the version to be published. LX: analysis and interpretation of data and drafting the article. HY and YL: contributed to data collection. YZ: interpretation of data, drafting the article, and approval of the version to be published. 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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In-home environment and happiness among older adults in Thailand

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Background: The fact that housing can play a critical role in maintaining the health and independence related to happiness of the older population has been studied in more developed countries. However, research on the effect of housing conditions on happiness is rare in less developed countries. This study aimed to construct and test a structural equation model describing the structural relationship among personal aspects (living alone and physical disability), in-home environment (sleeping place and toilet/bathroom), and happiness among older adults in Thailand.

Method: The data on the population age 75years or over were extracted from the 2017 national Survey of Older Persons in Thailand (*n*=7,829).

Results: The median age of the sample population was 79. Almost 60 percent were women. The structural equation model showed a good fit with the data. Living alone did not directly influence happiness. Physical disability had a statistically significant negative direct effect on happiness. In-home environment not only had an impact on happiness directly, but also moderated the relationship between physical disability and happiness.

Conclusion: The research suggested that interventions to improve happiness of older adults, particularly those with physical disability, should aim to adapt their housing, including sleeping place and toilet design.

KEYWORDS

happiness, housing condition, in-home environment, less developed country, living condition, older adults, physical disability, structural equation modeling

1. Introduction

The factors associated with happiness among older people have been of increased interest to researchers in recent decades. This may be due not only to the accelerating pace of population ageing around the world, especially the oldest-old and increased longevity among older adults (1), but also the benefit to the nation in having a society with happy members. Longevity is, however, a pressing issue for public health, not least because of the greater likelihood of frailty and disability in older age (2).

One of the most common consequences of aging is functional health decline. The association of physical health with human well-being is well-understood. It has been found that the presence of disability is an important determinant of happiness and survival among older adults (3–7). This may lead to several studies focusing on a person-environment, fit-oriented analysis for

healthy aging (a positive view of aging) (8) which is advocated by the World Health Organization's International Classification of Functioning, Disabilities, and Health (ICF) (9). According to the ICF, statistical relationships are expected to be found between physical functioning, social participation, personal characteristics, and environmental factors, including in-home environment (10). An appropriate indoor environment (or age-friendly housing) for those with limitations includes the availability of support mechanisms (e.g., to prevent falls), having proper material for daily living, and age-friendly facility design. Health-related safety in the home needs to be addressed in happiness studies among older populations since, as people grow old, they spend more time in the home. Safety could be conceptualized as preventing or reducing the risk of problems that could undermine older people's ability to live independently at home (11). According to the framework for health-related safety of Lau et al. (12), risk is associated with individual functioning and behavior (e.g., physical decline), and the social and physical environment (e.g., social isolation and in-home hazards), particularly among those living alone.

As population aging progresses, the prevalence of older-single-person households increases as well. There is a link between types of living arrangement (particularly living alone) and happiness among older adults. In general, those who live alone are more likely to feel lonely and less happy than those living with others. However, when an older person voluntarily chooses to have a single-person household, his/her choice may have a positive effect on their sense of well-being. It is possible that s/he may feel more stress due to various restrictions when one must live with other family members (13). Nevertheless, co-residence with kin or others is often arranged when older adults need daily personal care as they age. An inverse relationship may occur as well, i.e., very old adults living alone have a pronounced risk of losing independence and becoming socially isolated. Importantly, the in-home environment needs to be modified to support older adults living with disability or living alone in order for them to stay independently in their homes.

Appropriately modified homes may protect individuals from accidental injury, and provide them with adequate long-term housing, permitting greater autonomy and preserving social ties (14). The association between the housing environment and well-being has been studied extensively among older adults living alone in the age range of 75–89 years, especially in the European countries of Sweden, Germany, United Kingdom, Latvia, and Hungary (15, 16). For instance, Oswald, Wahl, Mollenkopf, and Schilling (17) conclude that housing conditions played an important role in life satisfaction for older people (age 55–99 years) in two rural regions of Germany. Similarly, quality housing and a feeling of home attachment were associated with psychological well-being among the population age 60 years or over living independently (alone or with another older adult) in the United States (18). In urban China, a study found that housing conditions, housing satisfaction, and home ownership had an impact upon life satisfaction among those between 18 and 69 years of age (19). Also, in China, a recent study found that the housing environment was associated with depressive symptoms among older adults aged 60 or over (20). Nevertheless, studies that have examined the relationship between housing conditions and happiness among older adults are rare in less-developed countries.

Thailand is a middle-income country in Asia where aging is occurring very rapidly, and Thailand is currently ranked 8th in Asia in terms of the percentage of the population age 60 years or over. In 2019, these older adults accounted for 18 percent of the total Thai

population, and the proportion is projected to reach 28 percent by the year 2037. The rate of population growth is highest among the "oldest-old" (i.e., 80 years or over) (21). Many of these older persons may have difficulty in performing activities in daily living (ADL), and the majority will spend most of their time in their home residence. The challenge is how to enable older people in Thailand, especially those in the mid-and oldest-old groups who had high dead rate from fall (22), to live safely and happily in their home environment, given the traditional Thai filial piety norms and government policy of "aging in place" (23).

Apart from rapid population aging, Thailand has undergone major socioeconomic and cultural changes in recent decades. The composition of Thai households has become more diverse and characterized by an increased prevalence of persons aged 60 years or over living alone: from 6 percent in 2002 to 11 percent in 2017 (21). Many Thai people have adopted a number of westernized, health-promoting lifestyles, e.g., switching from sleeping on the floor to sleeping on a bed, or using a sit-down toilet instead of a squat latrine (24). Previous studies of happiness among older Thais found that economic hardship, relative poverty, living arrangement, functional ability, social environment, family and friendship support, and healthy lifestyle behaviors were associated with happiness, psychological well-being, and/or life satisfaction (25–27). No study, however, includes the in-home environment as a determinant of happiness of older persons in Thailand. In addition, most studies in and outside of Thailand are cross-sectional, and use non-causal relationship analyses. Thus, this study attempted to fill gaps in the national and international research literature and test an analytical model of the structural relationship among personal aspects, in-home environment aspects, and happiness among older adults in Thailand (controlling for other generally acknowledged determinants). This report concludes with suggested interventions, based on causal-relationship findings, to support Thailand's "aging-in-place" policy.

2. Materials and methods

2.1. Research model and hypothesis setting

Based on the literature review, a causal model of the relationship between personal factors, in-home environment, and happiness is proposed (Figure 1). The study hypothesis assumes two exogenous

FIGURE 1
Hypothesized model.
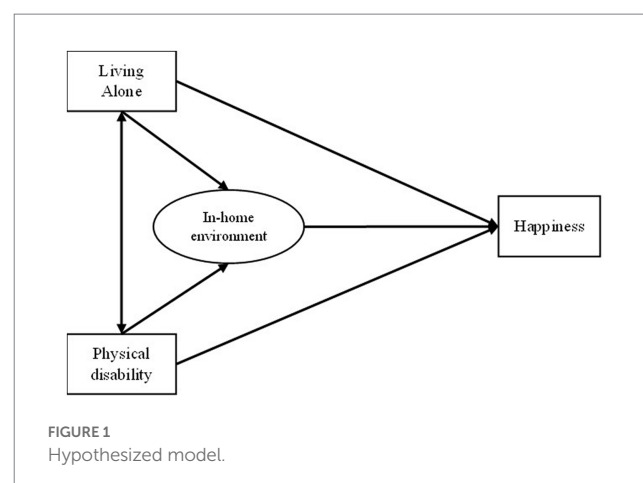
variables, one mediating variable and one endogenous variable. The two exogenous variables are living alone and physical disability. Happiness is the endogenous variable. In-home environment is considered a mediating variable that influences the relationship between the two exogenous variables and happiness. Thus, the present study analyzed the direct, indirect, and total effects of exogenous variables, and the direct effects of the mediating variable on happiness.

2.2. Data collection and procedures

Data for this study were derived from the Survey of Older Persons in Thailand, which was carried out by the Thai National Statistical Office (NSO) in 2017. That survey includes a representative sample of 41,752 persons aged 60 years or over. The NSO used a two-stage stratified sampling design. The first stage included sample blocks in municipal areas and sample villages in rural areas in all provinces of Thailand. Private households were sampled in the second stage, and those age 60 years or older in all selected households were interviewed face-to-face. However, for 8,995 cases, information was obtained by proxy response (i.e., from members in the household and/or non-household members), and these cases were excluded from the analysis in the present study. Thus, there were 32,757 respondents interviewed directly. Persons aged 75 years or older were selected for this study since loss of independence rapidly increases with advanced age in most individuals. Thus, the final sample comprises 7,829 respondents. The results were weighted, and Structural Equation Modeling (SEM) was used to test the hypotheses.

SEM is a statistical model which displays the causal relationships among several variables in a path diagram (28). SEM is also referred to as a combination of multiple regression and factor analysis. SEM is used to reduce the limitation of regression equations that allow the occurrence of an error of measurement in the endogenous and exogenous variables. In addition, SEM allows interpretation of the direct (linear influences) and indirect effects (nonlinear influences) among the study variables (29). SEM was performed using the software package AMOS Version 18. This study was approved by the Institutional Review Board (IRB) of the Institute for Population and Social Research of Mahidol University (COE. No. 2021/06–122).

2.3. Assessment of study variables

The respondents were asked to assess their level of happiness based on the following question: "In the past 3 months, what was the level of your happiness?" The potential response scores range from 0 to 10, where 0 means "unhappiest" and 10 "happiest." A single-item instrument referring to happiness is commonly used for well-being research (30, 31). One study found that measuring happiness using a single question was reliable and valid since the answers had a high positive correlation with those provided by other happiness scales or inventories (32).

A favorable in-home environment for independent living in this study refers to a situation in which "The physical surroundings in the house support older occupants to perform ADL, including having a

bed, having a sit-down toilet, presence of handrails in the bedroom/toilet/bathroom, and having an in-house toilet." In-home environment was assessed using four items: Sleeping place, toilet/bathroom, presence of handholds in both these settings, and location of the toilet -- indoors or outdoors. The first question was as follows: "Where do you sleep?" with potential answers of on the floor or on a bed. The second question was: "What type of toilet do you use?" with potential answers of sit-down toilet or squat latrine. The third question was "Does your house have handrails in the bedroom/toilet/bathroom?" with potential answers yes or no. The fourth question was "Where is your toilet/bathroom located?" with potential answers of in the house or outside the house. Confirmatory Factor Analysis was used to test whether these components can be appropriately aggregated into a single in-home environment construct. It was found that the five components of the in-home environment model indicated overall good fit according to various fit indices: $\chi^2 = 86.626$ ($p < 0.001$), GFI = 0.953, NFI = 0.953, CFI = 0.953, and RMSEA = 0.05, indicating the model had good fit (28, 33).

Physical disability was assessed according to the following eight ADL: bathing, dressing, toileting, continence, feeding, getting up from a lying down position, squatting, and climbing 2–3 stairs. The question was "Can you perform (the above ADL) … by yourself?" The potential answers were classified into two groups: Yes, could do by self (score = 0), and with difficulty (i.e., could not do at all or need assistance) (Score = 1). The possible score range is 0 to 8, with the lowest score denoting no physical disability, and the highest score denoting dependence on others for all ADL.

Living arrangement was categorized into "living alone" or "living with other (s)." It was based on the question "How many persons live in this household?" In this study, living alone refers to older adults living in this household without anyone else.

Demographic and socioeconomic characteristics including age, sex, marital status, educational attainment, and personal income were also included in the analysis as control variables. These factors were found to be associated with happiness among older adults (5).

3. Results

3.1. Characteristics of the sample

Table 1 shows that more than half the total sample were those age 75–79 years while persons aged 80 years or over constituted 45.8 percent. Almost 60 percent were females, and 45.6 percent of the sample were currently married. About three-fourths had completed only primary school, and half the sample had personal income under 30,000 baht (about $1,000) per year.

About one in six of these older Thais lived alone (16.7 percent). Three out of five had no physical disability, while about one in five had difficulty in performing one ADL. Regarding in-home environment, three out of five respondents slept on a bed while the rest slept on a mat or mattress on the floor. Almost the same proportion (61 percent) had handrails in the bedroom. About half the sample used a sit-down toilet, but only 13 percent had handrails next to the toilet. Four out of five said that their toilet was located inside the house.

TABLE 1 Characteristics of the sample and mean happiness score (*n*=7,829).

Characteristics	%	Happiness Score	
		Mean	SD
Age group (Mean = 80.08, Median = 79.00, SD = 4.39, Min = 75 Max = 103)			
75–79	54.2	6.86	1.40
80 or over	45.8	6.70	1.43
Sex			
Male	40.7	6.82	1.40
Female	59.3	6.77	1.43
Marital status			
Single, Widowed, Divorced	54.4	6.77	1.42
Married	45.6	6.81	1.42
Educational attainment			
No formal education	14.2	6.60	1.45
Primary school	77.4	6.76	1.40
Secondary school	6.0	7.26	1.39
Bachelor's or higher degree	2.4	7.64	1.41
Personal income per year (baht)			
Less than 10,000	15.2	6.50	1.48
10,000–29,999	38.5	6.54	1.39
30,000 - 49,999	21.3	6.95	1.35
50,000 - 79,999	14.3	7.03	1.33
80,000 or above	10.7	7.45	1.37
Living arrangement			
Alone	16.7	6.71	1.45
With other(s)	83.3	6.80	1.41
Physical disability			
0	60.3	6.94	1.34
1	21.4	6.77	1.43
2	12.1	6.47	1.50
3	3.3	6.11	1.43
4	0.9	6.07	1.44
5	0.6	5.80	1.75
6	0.5	5.59	1.67
7	0.5	5.08	1.86
8	0.4	5.56	1.54
Sleeping place			
Floor	40.5	6.59	1.40
Bed	59.5	6.92	1.42
Handrails in bedroom			
No	39.0	6.66	1.46
Yes	61.0	6.87	1.39
Toilet type			
Squat latrine	48.3	6.57	1.38
Sit-down	51.7	6.99	1.42

(Continued)

TABLE 1 (Continued)

Handrails in toilet/bathroom			
No	86.9	6.76	1.42
Yes	13.1	6.99	1.40
Location of toilet/bathroom			
Outside the house	18.4	6.48	1.41
Inside the house	81.6	6.86	1.41

3.2. SEM analysis

The SEM model and its standardized direct and indirect coefficients (controlled for age, sex, marital status, educational attainment, and personal income) are presented in Figure 2. The coefficients for direct, indirect, and total effects with confidence intervals are described in Tables 2, 3.

The SEM model showed a good fit with the data, $\chi^2 = 302.397$ ($p < 0.001$), goodness of fit index (GFI) = 0.964, normed fit index (NFI) = 0.959, comparative fit index (CFI) = 0.964, and root mean square error of approximation (RMSEA) = 0.10. Among the direct effects, the analysis found that in-home environment was the most significant predictor of happiness among Thai older adults (0.235). Physical disability had a significantly negative effect on happiness (−0.216) and a significantly positive effect on in-home environment (0.113). Living alone did not significantly affect happiness (−0.013), but it had a significantly negative impact on in-home environment (−0.082). This study also found that living alone was not significantly predicted by physical disability (−0.017) and vice versa.

In-home environment was defined as a mediating variable in the research model to verify mediation effect significance among exogenous variables (i.e., living alone and physical disability) and the endogenous variable (happiness). The analysis found a significant indirect effect of living alone and physical disability on happiness (−0.019 and 0.026 respectively) (Table 3). It should also be noted that the indirect effect of living alone on happiness, as mediated by physical disability alone and physical disability plus in-home environment, was not significant and equal to 0.000, suggesting that there could be no effect. Similarly, the indirect effect of physical disability on happiness mediated by living alone and living alone plus in-home environment was not significant and equal to 0.000, suggesting that there could be no effect as well.

The total effects (shown in Table 3) indicate the greater importance of physical disability on happiness than living alone. Moreover, the negative coefficient of the total effect of physical disability decreased compared with the direct effect (from −0.216 to −0.190), suggesting that the mediating factor (in-home environment) helped increase happiness among older adults with physical disability.

4. Discussion

The present study investigated whether the role of the in-home environment had a significant impact on happiness directly and/or moderated by the relationship between living independence (i.e., living alone and physical disability) in a national sample of Thais age 75 years or over. The SEM model presented a good fit, indicating that our hypotheses offered a plausible explanation of how the in-home
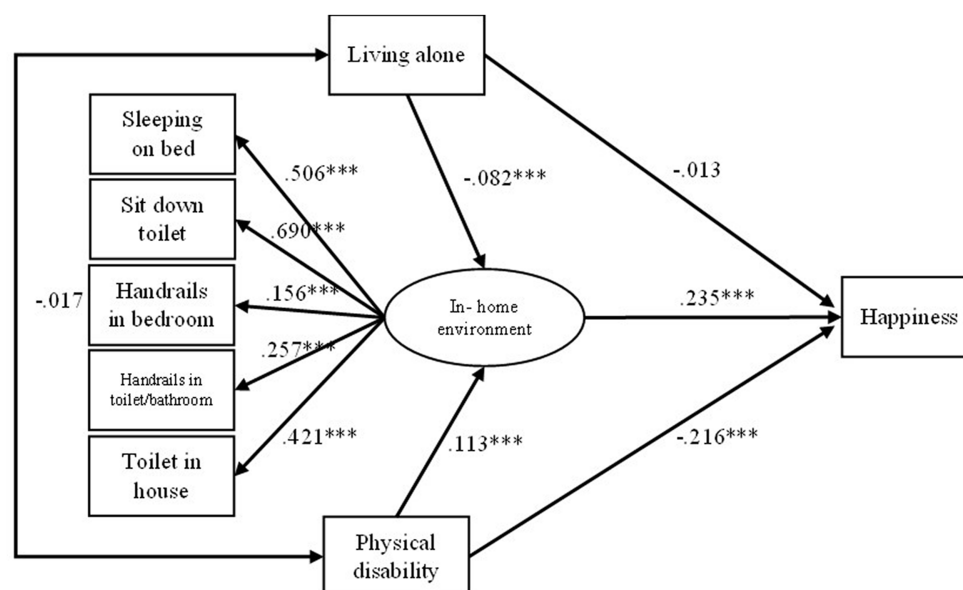
FIGURE 2
Structural model of happiness of Thai older adults. Control variables were age, sex, marital status, educational attainment, and personal income per year; *p<0.05, **p<0.01, ***p<0.001; Model fit indices: χ^2=302.397 (p<0.001), GFI=0.964, NFI=0.959, CFI=0.964, and RMSEA=0.10.

TABLE 2 Direct effects of the model controlling for age, sex, marital status, educational attainment, and personal income per year (standardized regression coefficients).

Direct effects	Factor loadings (β) (95% CI)
Physical disability ↔ Living alone	−0.017 (−0.038 to 0.003)
Living alone → In-home environment	−0.082*** (−0.113 to −0.054)
Physical disability → In-home environment	0.113** (0.086 to 0.140)
Age → In-home environment	0.046** (0.018 to 0.073)
Gender → In-home environment	−0.100*** (−0.130 to −0.070)
Marital status → In-home environment	0.038* (0.005 to 0.070)
Education → In-home environment	0.334*** (0.310 to 0.358)
Personal income → In-home environment	−0.154*** (−0.181 to −0.126)
In-home environment → Happiness	0.235*** (0.203 to 0.266)
Living alone → Happiness	−0.013 (−0.038 to 0.011)
Physical disability → Happiness	−0.216*** (−0.241 to −0.193)
Age → Happiness	−0.026* (−0.049 to −0.004)
Gender → Happiness	0.011 (−0.013 to 0.035)
Marital status → Happiness	−0.034** (−0.060 to −0.009)
Education → Happiness	0.030* (0.004 to 0.057)
Personal income → Happiness	−0.033** (−0.055 to −0.010)

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

environment is related to happiness, when controlling for the potential confounding effect of age, sex, marital status, educational attainment, and personal income.

4.1. Direct effect

Among the direct effects, happiness was mainly predicted by in-home environment (i.e., sleeping place and type of toilet): Older adults living in a better in-home environment were happier. This finding is similar to that of previous studies (18). However, living alone had no significant effect on happiness. That finding is inconsistent with previous studies. For example, a study by Hwang and Sim (31) found significant differences in happiness between types of living arrangement in which those living alone had the least happiness.

Those who had a higher level of disability were less happy, and that finding is consistent with many previous studies (4, 5). The significant negative direct link between living alone and in-home environment suggests that older adults who live alone were less likely to live in a better in-home environment. Those living alone tend to be a population subgroup selected for those with good health. Thus, they do not need in-home facilities to support ADL. This finding is consistent with the result of the analysis which found that living alone was not predicted by physical disability, and vice versa. This may be because most respondents in the sample had no disability or only a single physical disability (Table 1). As expected, those with physical disability were more likely to live in a better in-home environment, i.e., to support them in ADL.

4.2. Mediating effect

The analysis found that the path from living alone and physical disability to happiness is mediated by in-home environment. The path from living alone → in-home environment → happiness was significant with a negative coefficient. The total effects of living alone on

TABLE 3 Indirect and total effects of the research model controlling for age, sex, marital status, educational attainment, and personal income per year.

Path diagram	Factor loadings (β) (95% CI)		
	Direct effects	Indirect effects	Total effects
Living alone → In-home environment → Happiness	−0.013 (−0.038 to 0.011)	−0.019*** (−0.028 to −0.013)	−0.032** (−0.056 to −0.009)
Living alone → Physical disability → Happiness		0.000 (0.000 to 0.000)	
Living alone → Physical disability → In-home environment → Happiness		0.000 (0.000 to 0.000)	
Physical disability → In-home environment → Happiness	−0.216*** (−0.241 to −0.193)	0.026*** (0.019 to 0.034)	−0.190*** (−0.216 to −0.166)
Physical disability → Living alone → Happiness		0.000 (0.000 to 0.000)	
Physical disability → Living alone → In-home environment → Happiness		0.000 (0.000 to 0.000)	

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

happiness had a significantly negative increased coefficient compared to its direct and indirect effects. These findings suggest that, although older adults in single-person households lived in a better in-home environment, they may prefer living with others (i.e., family members). This is likely to be the case in many Asian countries such as China (13) and Thailand (34, 35), particularly when persons reached advanced age and need daily personal care. The significant, indirectly positive effect of physical disability → in-home environment → happiness, and the significant total effect of physical disability → happiness demonstrates that a more comfortable in-home environment (i.e., sleeping place and type of toilet) helped increase a sense of happiness among older adults with physical disability.

These findings support the Thai government policy of "*aging in place*" for the rapidly growing population of older adults (particularly the oldest-old) by identifying factors that predict self-perceived happiness persons aged 75 years or over and indicating which kinds of individuals can benefit from the modification of in-home environment (i.e., frailty in performing ADL). Two dimensions of the in-home environment (sleeping place and toilet/bathroom) were assessed in this study. The bathroom (i.e., availability of handrails, and toilet type) is a key factor since it is the most unsafe room in an older adult's home (36).

The findings reveal that the in-home environment of older Thais needs to be improved. About two in five older persons slept on the floor, and about the same proportion had no handrails in the bedroom. Although about four out of five older Thais had an indoor toilet/bathroom, about half used a squat latrine, and only one in ten had handrails in their toilet/bathroom. Housing without the proper sleeping place, elder-friendly toilet, and amenities to support frail older persons could increase the rate of accidental falls and injury among this growing segment of the population. Similar housing conditions were documented in another study in Thailand (37), and

that study found that many older people slept on a thin mat or mattress on the floor.

Older adults who slept on a bed, used a sit-down toilet, had handrails in the toilet/bathroom, and had an indoor toilet were happier than their counterparts who slept on the floor, used squat latrine, had no handrails in the toilet/bathroom, and had an outdoor toilet. Those with limited function ability may find it challenging to lie down on the floor and get back up again multiple times during the night. The presence of handrails in the toilet/bathroom and having an indoor toilet helped older persons in carrying out ADL. Additionally, the older adults (particularly those with physical disability) did not have to worry about hazards in the course of performing everyday functions.

That happiness among older adults with physical disability was mediated by in-home environment can be explained by the ecology theory of aging (ETA) (38). According to ETA, individuals with low functional capacity are much more vulnerable to environmental demands than those with high capacity. In addition, aspects of the living environment (e.g., sleeping place, type/location of toilet) are critical to what older persons can manage in their everyday lives. Thus, those who lived in a poorer housing environment felt less happy. However, the present study suggests that it should be possible to increase happiness of older persons by modifying the structure and amenities of the household. Thailand has been recognized as a success story for converting the population from defecating in open spaces or into a squat pit privy to using a sanitary latrine. A nationwide health education campaign was waged over many years to convince the population of how a sanitary latrine was healthier and a way to eliminate foul odors. Currently, the Thai Ministry of Public Health has a policy to replace all the squat latrines around the country with sit-down toilets. This policy was formulated in recognition of the exploding population of older persons and to reduce discrimination against persons with disabilities (24). That said, Thai families have limited knowledge about how to adapt their home to be elder-friendly. Fortunately, senior-friendly accommodations are increasingly used as a marketing tool in the Thai real estate sector, and the government plans to provide more of this type of affordable housing for middle-and lower-income older persons. In addition, a government allowance of up to 100,000 baht per household (~ $3,000) is available to help communities renovate the homes of older persons in order to make them safe and suitable for aging bodies (39, 40). It should also be noted that a Mexican government program to replace dirt floors with cement significantly improved the health of young children, as measured by decreases in the incidence of parasitic infestations and diarrhea, a decrease in the prevalence of anemia, and an improvement in childhood cognitive development. Additionally, the Mexican program demonstrated significant improvements in adult welfare as measured by increased satisfaction with housing and quality of life, as well as by lower scores on depression and self-perceived stress scales (41).

4.3. Limitation of this study

Because the data set was secondary, only a limited number of housing characteristics for ADL were available (i.e., sleeping place, type of toilet, handrails, location of toilet). Nevertheless, despite these limitations, the analysis was able to identify key in-home design variables that contribute to older adult-friendly housing. Future

studies should include more refined indicators of housing quality (e.g., kitchen area, floor material, etc.,).

In addition, cross-national interpretation of housing-related findings should be cautious. The findings from this study may be applicable to less-developed countries for two reasons. First, the measurement of suitable in-home environment for older adults are likely to be different between less developed and developed countries depending on differences in housing standard (15). Secondly, the living arrangements of older adults and, more specifically, living alone are the result of prevailing of cultural norms, the preferences and the resources people have, and the constraints they face as they age, such as the support from their families and public welfare. The prevalence of living alone is considerably higher in more developed countries (42). These amenities are widely different by level of country development.

5. Conclusion

This study found that the in-home environment of Thais age 75 years or over needs to be improved (e.g., sleeping place and toilet/bathroom). Sleeping on a bed, using a sit-down toilet, having handrails in both places, and having an indoor toilet had a positive, statistically significant direct effect on happiness of this sample of older persons. Physical disability also had a statistically significant negative direct effect on happiness. Additionally, in-home environment not only has an impact on happiness directly, but also moderates the relationship between physical disability and happiness. Therefore, there is a strong need for programs to ensure a safe living environment (e.g., adapted housing appropriate for ADL) for older adults in general, and for those with physical disability in particular.

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 Institutional Review Board (IRB) of the Institute for Population and Social Research of Mahidol University (COE. No.

2021/06-122). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

RG was responsible for the conception and design of this study. AP was responsible for data analysis. AP and RG were responsible for drafting and revising the manuscript and final approval of the manuscript submitted. 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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Malnutrition is associated with increased disease risk in older people in the Makkah region of Saudi Arabia: A cross-sectional study

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Introduction: There is little research on the nutritional status of older people in Saudi Arabia. This study investigated the factors associated with the nutritional status of older people in the Makkah region, Saudi Arabia. We hypothesized that older people who are at risk of malnutrition are at higher risk of different diseases.

Materials and methods: This cross-sectional study surveyed 271 people aged $\geq$60 years from October 2021 to January 2022. We collected data on demographics, body mass index, the Geriatric Depression Scale-Short Form, Geriatric Oral Health Assessment Index, Mini Nutritional Assessment, Eating Attitudes Test, and Household Dietary Diversity score.

Results: Among the 271 participants, 13.3% were malnourished and 53.9% were at risk of malnutrition. The oral health ($P < 0.001$), depression ($P < 0.001$), and eating disorder ($P < 0.002$) scores were significantly associated with malnutrition. Congestive heart failure, asthma, peripheral vascular disease, Alzheimer's disease, and hypertension were more prevalent among malnourished participants—this supports our original hypothesis. The HDD score showed no significant differences between men and women.

Conclusion: Malnutrition was associated with overweight or obesity, poor oral health, and depression. Older people in the Makkah region, Saudi Arabia, had a high risk of malnutrition.

1. Introduction

Health problems related to malnutrition have increased worldwide in the older population. Malnutrition refers to insufficient (undernutrition) or excess (overnutrition) nutrient intake that contributes to health conditions such as obesity, diabetes, and coronary heart disease (1, 2). Studies have reported that malnutrition is significantly associated with hospitalization in older people, and ∼90% of those in hospitals are malnourished or at risk of malnutrition (3). In Australia, 42.3% of older adults admitted to hospitals are malnourished (4). Many psychological and biological changes, such as loss of taste and smell sensitivity, chewing difficulties due to missing teeth, and impaired activities of daily living (5), which

affect the intake of certain foods and nutrients are associated with old age and increase the risk of nutrition-related health problems.

Globally, the older population is rapidly expanding (6, 7), with individuals aged ≥ 65 years accounting for 10% of the global population (1). According to the World Health Organization (WHO), the older population will reach 1.2 billion by 2025, with most residing in low-income countries (7). Furthermore, it has been suggested that by 2025, the percentage of older people worldwide will increase by 300% above that in 2000 (8). With improved medical care and living conditions, Saudi Arabia's demographics are slowly but steadily changing, with life expectancy increasing in recent decades (8). *Here, an estimated 4.3% of the population were aged 55–64 years in 2013, while it is predicted that 18.4% will be aged ≥ 65 years in 2050* (9). Saudi Arabia has witnessed remarkable development in socioeconomic status in the past 40 years, combined with significant lifestyle changes, such as the adoption of Western dietary patterns and reduction in physical activity levels, which has led to a high prevalence of chronic diseases and nutrition-related health problems among different age groups, including older people (10).

Malnutrition increases the risk of morbidity and mortality in the older population (11). Previous research has shown that malnutrition is associated with several factors, including socioeconomic factors (education, sex, and marital status) (12, 13), eating habits (14), and psychological (depression and dementia) (15) and medical factors (osteoporosis, dysphagia, and oral health problems) among older people (16–18). Hence, early detection and treatment of malnutrition in older people is critical for reducing morbidity and improving quality of life. Malnutrition has been reported to be prevalent in 25.6% of older adults in Bangladesh (19) and 17.9% in India (6). However, a previous study showed that only 5.8% of older adults in developed countries, including Switzerland, Sweden, and Japan, are malnourished (20). There is a paucity of research on the nutritional status and factors associated with malnutrition among older people in Saudi Arabia. Therefore, this study aimed to address this gap and investigate the factors associated with the nutritional status of the older population in the Makkah region of Saudi Arabia. We hypothesized that older people who are at risk of malnutrition are at higher risk of different diseases.

2. Materials and methods

2.1. Study design and participants

This cross-sectional study surveyed 271 men and women aged ≥ 60 years in the two largest cities in the Makkah region of Saudi Arabia, Makkah and Jeddah, from October 2021 to January 2022. As defined by the United Nations, individuals aged ≥ 60 years were considered as the older population (21). According to the General Authority for Statistics, a total of 321 769 people (both Saudis and non-Saudis) aged ≥ 60 years were living in the Makkah region during the time of data collection (22). Sample size calculation revealed that a sample of 271 was required to achieve sufficient statistical power based on a 90% confidence level, 5% margin of error, and 50% response distribution (23). The main inclusion criteria were an age ≥ 60 years and the ability

to answer questions independently or with assistance from a caretaker. Participants were excluded if they had feeding tube, cognitive or physical disabilities, or were admitted to hospitals or institutions. This study was onducted in accordance with the guidelines of the Declaration of Helsinki, and all procedures were approved by the Biomedical Ethics Research Committee of King Abdulaziz University (Reference No. 503-21). Written informed consent was obtained from all participants. Data on all participants were collected *via* face-to-face interviews in public places, such as parks, malls, walking paths, Jeddah Corniche, and primary health care centers.

2.2. Data collection tools

2.2.1. Demographic and anthropometric characteristics

Data on the demographic characteristics of the participants, such as age, sex, nationality, and marital status, were obtained. The following additional questions were asked: "Do you use food delivery applications?" (Answers: yes/no) and "Who prepares your food?" (Answers: myself/family/nobody). After the participants were interviewed, height (centimeters) and weight (kilograms) measurements were taken in light clothing using a standard scale. Body mass index (BMI), calculated by dividing the weight by height squared (kg/m^2), was grouped according to the WHO categories ($<18.5\ kg/m^2$, underweight; $18.5–24.9\ kg/m^2$, normal weight; $25.0–29.9\ kg/m^2$, overweight; $30.0–34.9\ kg/m^2$, obese; and $\geq 35\ kg/m^2$, severely obese) (24). Given that only four and six participants were classified as being underweight and severely obese, respectively, we combined the data of participants who were underweight with that of those with a normal weight for the analysis. Similarly, the data of participants who were severely obese were combined with that of those who were obese.

A validated semi-structured questionnaire for data collection through face-to-face interviews was developed based on previous studies that used the Geriatric Depression Scale-Short Form (GDS-SF) (25, 26), Geriatric Oral Health Assessment Index (GOHAI) (27, 28), Mini Nutritional Assessment (MNA) scale (29, 30), Household Dietary Diversity (HDD) score (31, 32), and Eating Attitudes Test (EAT-26) (33, 34). To ensure reliability and validity, the researchers translated the tools into Arabic. These were subsequently sent to 15 participants for pre-testing, following which necessary changes were made to ensure that the questionnaire was culturally consistent.

2.2.2. Geriatric depression scale-short form

This scale involved 15 questions that were highly associated with depressive symptoms based on the original GDS validation studies (25, 26). The GDS-15 examined the participants' mood. The given answers (yes/no) were based on how the participant felt in the past week. Depending on the question, 1 point was awarded to either a "yes" or "no" answer. Scores of 0 to 4 points were considered normal mental health, and 5 to 15 points were indicative of depression.

2.2.3. Geriatric oral health assessment index

The GOHAI comprised 12 questions. Responses on a Likert scale were used to assess oral health problems that might affect daily life, including physical functions, such as eating, swallowing, and speaking; and psychosocial functions, such as worrying or concerns regarding oral health and self-image, in addition to self-consciousness of oral health and limitation of contact with people due to oral health problems. The scale also assessed pain and inconvenience. Responses were scored as follows: never = 5, seldom = 4, sometimes = 3, often = 2, and always = 1. Scores ranging from 57 to 60 were considered adequate oral health, scores ranging from 56 to 51 were considered moderate oral health, and scores ≤50 were considered poor oral health (27, 28).

2.2.4. Mini nutritional assessment questionnaire

The MNA is a screening and assessment tool for older people that consists of 18 items. In this study, 16 items were used as the questions regarding mid-arm and calf circumferences were excluded. The tool is divided into two parts: the first part, which consists of questions regarding BMI, mobility, and weight loss, is used for screening, while the second part consists of questions regarding the living situation of participants, number of drugs used per day, self-perceptions of health and nutrition, and consumption of food and fluid. Each answer was scored and the sum of the points indicated the respondent's status. Participants with scores <17, 17–23.5, and ≥24 were considered malnourished, at risk of malnutrition, and well-nourished, respectively (29, 30).

2.2.5. Eating attitudes test

Eating attitudes and behaviors were evaluated using the EAT-26 self-report questionnaire. The scale had three subscales with 26 questions about dieting, bulimia, and oral control. The questionnaire was related to beliefs, behaviors, and attitudes about food, weight, and body shape (33). Each item, except the behavior subscale, had six response options with scores ranging from 0 to 3 (always = 3, usually = 2, often = 1, sometimes = 0, rarely = 0, and never = 0). The behavior subscale had reversed scores ("never," "once a month or less," and "2–3 times a month" = 0; "once a week" = 1; "2–6 times a week" = 2; and "once a day or more" = 3). The overall score was equal to the sum of the scores of the 26 items. A score of ≥20 was characteristic of a disordered eating attitude (34).

2.2.6. Household dietary diversity score

The HDD score was determined based on how many food groups were consumed in a week. The method was adapted from that of Clausen et al. (31). Twelve food groups were used to calculate the HDD score: (1) cereals; (2) roots and tubers; (3) vegetables; (4) fruits; (5) meat, poultry, and offal; (6) eggs; (7) fish and seafood; (8) legumes, nuts, and pulses; (9) milk and dairy products; (10) oil/fats; (11) sugar/honey; and (12) miscellaneous food types. For each food category, a score of 1 (if consumed) or 0 (if not consumed) was assigned. The HDD score, which ranged from 0 to 12, was determined by the total number of food categories consumed by the entire household. It was categorized based on

the Food and Agricultural Organization of the United Nations' (32) recommendation: lowest dietary diversity (≤4 food groups), medium dietary diversity (>4 and <7 food groups), and high dietary diversity (≥7 food groups).

2.3. Statistical analyses

Descriptive statistics are presented as means and standard deviations. Linear regression models were used to assess the association of older age groups and nutritional status with oral health, depression, and eating disorder status, with age, sex, BMI, and marital status as covariates. Logistic regression models were constructed to determine the odds ratio (OR) between nutritional status and demographics (sex and age), BMI, oral health, depression, and eating disorders. In the logistic regression analysis, we combined the small number of participants with malnutrition (36 participants) with those at risk of malnutrition (146 participants) into a single group defined as the group at risk of malnutrition. Chi-square tests were used to analyze differences between nutritional status and comorbidities.

The life expectancy in Saudi Arabia in 2020 was estimated at 75 years (35); therefore, we opted for 70 years as the cutoff point to compare data between age groups, especially considering that most participants in this study were at the younger end of the age range of older people (<70 years). If we had opted for 75 years as the cutoff point, the comparison would not have been equivalent. Additionally, in Saudi Arabia, one in four adults have obesity or diabetes (36) (no data available for older people), and the prevalence of chronic diseases in Saudi men is high. One study reported that the percentage of participants aged ≥55 years with one and two or more chronic diseases is 31 and 34.5%, respectively. Furthermore, the prevalence of chronic diseases increases with age and obesity (37).

Statistical analyses were performed using SPSS version 28 (IBM Corp., Armonk, NY, USA). A P-value of 0.05 was set as the statistical significance level for all tests.

3. Results

Women represented 49% (men, 51%) of the participants enrolled in the study (Table 1). The mean age of the men and women was 69.2 ± 8.9 years and 68.4 ± 8.4 years, respectively (minimum 60 years and maximum 115 years for the total sample size). The mean BMI of the men and women was 28.4 ± 6.1 kg/m^2 and 29.3 ± 6 kg/m^2, respectively. According to the BMI categories, in the total sample, 25.1% of the participants had a normal weight, 36.2% were overweight, and 38.7% were obese; in men, the percentages were 26.8, 42.3, and 31.9%, respectively, and in women, 23.3, 30.8, and 45.9%, respectively. Of the participants, 73.8, 21.4, and 4.8% were married, widowed, and divorced, respectively. There were more married men (83.3%) than there were married women (63.9%; $P < 0.001$). The majority of the participants did not use food delivery services and their families prepared meals for them. This was particularly true for men where 92.8%, compared with 48.9% of women, reported that their families prepared meals for them ($P < 0.001$). Regarding health questionnaire responses, 72.3%

TABLE 1 Characteristics of the study participants.

Characteristics	Total	Men (n=138)	Women (n=133)	P-value
Age (years)	68.8 ± 8.7	69.2 ± 8.9	68.4 ± 8.4	0.45
Age range				
60–69 years	161 (59.4)	78 (56.5)	83 (62.4)	0.27
70–79 years	75 (27.7)	44 (31.9)	31 (23.3)	
≥80 years	35 (12.9)	16 (11.6)	19 (14.3)	
Body mass index (kg/m^2)				
BMI mean	28.8 ± 6.1	28.4 ± 6.1	29.3 ± 6	0.19
Normal weight	68 (25.1)	37 (26.8)	31 (23.3)	0.05
Overweight	98 (36.2)	57 (42.3)	41 (30.8)	
Obese	105 (38.7)	44 (31.9)	61 (45.9)	
Nationality				
Saudi	249 (91.9)	125 (90.6)	124 (93.2)	0.51
Non-Saudi	22 (8.1)	13 (9.4)	9 (6.8)	
Marital status				
Married	200 (73.8)	115 (83.3)	85 (63.9)	<0.001
Widowed	58 (21.4)	14 (10.1)	44 (33.1)	
Divorced	13 (4.8)	9 (6.5)	4 (3)	
Use of food delivery				
Yes	41 (15.1)	21 (15.2)	20 (15)	1.0
No	230 (84.9)	117 (84.8)	113 (85)	
Food preparation				
Myself	75 (27.7)	9 (6.5)	66 (49.6)	<0.001
Family	193 (71.2)	128 (92.8)	65 (48.9)	
Nobody	3 (1.1)	1 (0.7)	2 (1.5)	
Oral health status				
Poor	196 (72.3)	101 (77.7)	95 (76.6)	0.20
Moderate	55 (20.3)	29 (22.3)	26 (21)	
Adequate	3 (1.1)	0	3 (2.4)	
Depression score				
Normal	154 (56.8)	87 (63)	67 (50.4)	0.01
Mild	88 (32.5)	37 (26.8)	51 (38.3)	
Moderate	16 (5.9)	11 (8)	5 (3.8)	
Severe	13 (4.8)	3 (2.2)	10 (7.5)	
EAT-26 score				
Normal	209 (77.1)	109 (80.1)	100 (78.1)	0.76
Eating disorder	55 (20.3)	27 (19.9)	28 (21.9)	
MNA score				
Malnutrition	36 (13.3)	11 (8)	25 (18.8)	0.02
At risk of malnutrition	146 (53.9)	81 (58.7)	65 (48.9)	
Normal nutritional status	89 (32.8)	46 (33.3)	43 (32.3)	
Household dietary diversity score	9.8 ± 1.7	9.8 ± 1.8	9.9 ± 1.6	0.71

Data are presented as *n* (%), except for age and body mass index which are presented as mean ± standard deviation.

EAT-26, Eating Attitudes Test; MNA, Mini Nutritional Assessment.

P-values were calculated using an independent *t*-test for age, body mass index, and household dietary diversity score, and the Chi-square test for all categorical variables.

of the participants had poor oral health, 43.2% felt depressed (ranging from mild to severe), and 67.2% were malnourished or at risk of malnutrition. Men tended to feel less depressed ($P = 0.01$) and were more at risk of malnutrition ($P = 0.02$) than were women. Among the participants at risk of malnutrition, 14.3% reported weight loss of more than 3 kg in the previous 3 months, 25.3% reported weight loss of 1–3 kg, 26.4% reported no weight loss, and 32.4% did not know if they had lost weight. However, only 20.3% had eating disorders. The mean HDD score of the study participants was 9.8 ± 1.7 and there were no significant differences between men (9.8 ± 1.8) and women (9.9 ± 1.6).

Table 2 compares the health status of older people aged 60–69 years, 70–79 years, and ≥80 years. Participants aged ≥80 years were at risk of depression (GDS score 7 ± 4.2) compared with those aged 70–79 years (GDS score 4.4 ± 2.9) and 60–69 years (GDS score 3.7 ± 3.1; $P < 0.001$) who had normal mean depression scores. Furthermore, the mean HDD score was significantly higher in participants aged 60–69 years (10.1 ± 1.7) than in those aged 70–79 years (9.4 ± 1.8) and ≥80 years (9.7 ± 1.4; $P = 0.04$).

The association between nutritional status and other health conditions is shown in Table 3. Nutritional status was significantly associated with oral health ($P < 0.001$), depression ($P < 0.001$), and eating disorder scores ($P = 0.002$). Participants with malnutrition or at risk of malnutrition were depressed, had a poor oral health status, and had a higher risk of developing eating disorders compared with participants with a normal nutritional status.

Table 4 shows the adjusted ORs of nutritional status derived from the logistic analysis. The factors associated with higher odds of malnutrition were overweight or obesity (OR, 2.44; 95% confidence interval [CI], 1.25–4.77; $P = 0.009$), oral health (OR, 4.43; 95% CI, 2.28–8.58; $P < 0.001$), depression (OR, 0.21; 95% CI, 0.11–0.42; $P < 0.001$), and eating disorders (OR, 0.27; 95% CI, 0.11–0.62; $P < 0.002$). Additionally, older individuals with peripheral vascular disease ($P = 0.009$), asthma ($P = 0.04$), and hypertension ($P < 0.001$) had a significant risk of malnutrition. Among older participants, overweight or obesity, oral health, and depression were factors associated with an increased risk of being malnourished or at risk of malnutrition when compared with participants with a normal nutritional status (all $P ≤ 0.02$; data not presented).

The frequency of comorbidities among older people based on nutritional status is shown in Table 5. The frequency of congestive heart failure (30.6%), peripheral vascular disease (30.6%), cerebrovascular disease (11.1%), asthma or chronic lung disease (36.1%), liver disease (17.1%), peptic ulcer disease (47.2%), Alzheimer's disease or dementia (30.6%), rheumatic disease (33.3%), hypertension (74.3%), peripheral skin ulcer (25%), and depression (41.2%) was significantly higher among participants with malnutrition than among those at risk of malnutrition or with an adequate nutritional status.

4. Discussion

This cross-sectional study aimed to investigate the factors associated with the nutritional status of older people in the Makkah region of Saudi Arabia. The study revealed that malnutrition

among older people in Saudi Arabia was associated with oral health, HDD score, overweight or obesity, and depression. Furthermore, we found that compared with participants <80 years of age, participants ≥80 years were at higher risk of depression. In addition, a high percentage of the participants was obese, with a higher proportion of women being obese, and a higher proportion of men being overweight. Overall, this study revealed that older people at risk of malnutrition had significantly higher rates of peripheral vascular disease, asthma or chronic lung disease, peptic ulcers, Alzheimer's disease or dementia, hypertension, and depression than did participants with an adequate nutritional status. Thus, the study results support our hypothesis that older people with malnutrition are at higher risk of different diseases.

In this study, the proportion of participants with or at risk of malnutrition was 67%, which is consistent with the findings of studies from Australia (4) and India (38) that reported a proportion of 50–55%. In contrast, in Spain (6), Turkey (39), Sweden (40), and Hong Kong (12), the percentages were approximately one-third of those found in our study (27, 18.6, 17, and 1.1%, respectively), which may be explained by the high standard of health care for older people in these countries. The reported malnourished status could have resulted from unhealthy dietary choices and inadequate consumption of nutrient-rich foods. Another reason could be that systemic inflammation caused by obesity affects the absorption, distribution, and excretion of nutrients, thereby altering micronutrient metabolism (41). A study conducted among 782 French older adults (aged ≥65 years) found that 18% of overweight and 29% of obese individuals were at risk of undernutrition (42). Furthermore, in contrast with studies from India (6), Bangladesh (19), and France (42) that reported higher malnutrition rates among women than among men, we found that more men than women were at risk of malnutrition. A possible explanation for this might be that only 49% of women but the majority of men (92%) in our study were dependent on their families for food preparation. Previous studies have shown that poor health, a higher risk of diseases, and insufficient nutrient intake in older people may increase the risk of malnutrition. In addition, there are several factors associated with malnutrition or the risk of malnutrition, such as socioeconomic factors (low income, living alone [being single, widowed, or divorced], low education level), eating difficulties and disorders, and depression, especially in older people (40, 43–46). In the present study, the percentage of married men (83.3%) was higher than that of married women (63.9%); however, 21.4% and 4.8% of the participants were widowed and divorced, respectively. According to Bakker et al. (43), such participants may live alone without a helper, which may increase their risk of malnutrition compared with those who live with their families. Several studies have found that a significant percentage of older people at risk of malnutrition have a low socioeconomic status, such as low income and no education (13, 19), which influences dietary intake and eating patterns (13); however, we did not assess these factors in our study. These factors are related to age-related changes in taste, smell, dental health, and biological and physical activities, which can reduce the quality and quantity of nutrient intake and increase the risk of malnutrition in older people (6, 47, 48).

TABLE 2 Association of age with nutritional status and other health conditions.

Variables	60–69 years	70–79 years	≥80 years	P-value*
Oral health score	42.7 ± 9.1	42.3 ± 8.5	40.5 ± 9.1	0.65
Depression score	3.7 ± 3.1	4.4 ± 2.9	7 ± 4.2	<0.001
Eating disorder score	14.5 ± 12.6	12.6 ± 9.3	11.6 ± 8.8	0.11
Nutritional status score	21.9 ± 4.1	21.6 ± 4.6	19.2 ± 4.4	0.05
Household dietary diversity score	10.1 ± 1.7	9.4 ± 1.8	9.7 ± 1.4	0.04

*P-values were calculated using linear regression adjusted for sex, body mass index, and marital status.
Data are presented as mean ± standard deviation.

TABLE 3 Association between nutritional status of older people and other health conditions.

Variables	Malnourished (n = 36)	At risk of malnutrition (n = 146)	Normal nutritional status (n = 89)	P-value*
Oral health score	38.3 ± 8.8	40.5 ± 8.7	46.6 ± 7.5	<0.001
Depression score	8.1 ± 3.5	4.4 ± 2.9	2.6 ± 2.4	<0.001
Eating disorder score	16.5 ± 10.8	15.1 ± 12.9	10.1 ± 7.5	0.002
Household dietary diversity score	9.6 ± 1.5	9.7 ± 1.8	10.1 ± 1.6	0.11

*P-values were calculated using linear regression adjusted for sex, age, body mass index, and marital status.
Data are presented as mean ± standard deviation.

Eating difficulties are an important risk factor for malnutrition and can be caused by gradual muscle degradation, loss of teeth, and loss of motor coordination, leading to difficulties with the handling of food, putting food in the mouth, and chewing and swallowing (dysphagia) (39, 44). These difficulties can lead older people to opt for foods that are low in fiber and nutrients (44), which may increase their risk of malnutrition. In this study, 72.3% of the participants reported that they had poor oral health and 67% were at risk of malnutrition. In older people, There was a significant association between older people with poor oral health (chewing or swallowing difficulties) and being malnourished or at risk of malnutrition, which is consistent with the results of a Lebanese study (45) that used the GOHAI score and reported that 75% of older people had poor oral health and 41.5% were malnourished or at risk of malnutrition. Similarly, studies in Bangladesh (46) and India (38) have reported that 63% and 59.5% of older people who were malnourished, respectively, had poor oral health, whereas in Japan (49), the result (29.6%) was less than that reported in our study.

The mean HDD score was significantly higher in participants aged 60–69 years compared to in those aged ≥70 years; it was also high in comparison with that found in developing countries where there is limited HDD with food options mainly based on starchy staple foods (50). For example, the HDD score among the older population was found to be low in Sri Lanka (51), South Africa (52), and China (53). In contrast, the HDD score among older women was high in the United States (54). The high HDD score found in this study might be a result of high food availability and variability for older adults. In Saudi Arabia, family support and social relationships may play an important role in increasing HDD—family, friends, and neighbors can provide social and economic support (55). In addition, families in Saudi Arabia function as a unit socially and emotionally. Younger members

of the family serve older members, and the concept of sending an older member to a nursing home is unacceptable in Saudi culture (56).

After 50 years of age, various changes occur in body composition, such as increases in fat mass and decreases in lean mass (sarcopenia) (57). Therefore, the basal metabolic rate decreases by ∼15% between the ages of 30 and 80 years, which consequently reduces energy requirements. However, appetite and nutrient requirements remain the same or increase, which can further lead to weight gain during this age period (58). The frequency of obesity, which is associated with several chronic diseases, such as diabetes, hypertension, and cardiovascular disease, increases in older people aged between 60 and 70 years, particularly in women (59, 60). A high percentage of our study participants were obese (38.7%) and overweight (36.2%), and obesity was more prevalent in women (45.9%) than in men (31.9%), while more men were overweight (41.3%) than were women (30.8%). This is in contrast with the results of other studies showing that older women often have eating disorders because they are still concerned about their body shape (61, 62). In relation to other countries, similar trends in BMI status and the prevalence of overweight have been observed in older men (49 and 31.5%, respectively) and older women (39.8 and 40.8%, respectively) in Spain (63), while a comparatively lower prevalence of obesity has been observed in older people in India (32.5% in both men and women) (6). Our finding was also consistent with that of a study in Scotland (64), which found that obesity prevalence was particularly higher in older women. In the present study, participants at risk of malnutrition had low HDD scores compared with those with a normal nutritional status. Lv et al. found an inverse relationship between HDD score and mortality risk in older adults, with a 44% lower mortality risk among participants with the highest HDD score (65). A study in the United States found a correlation between HDD and BMI in women (54). Furthermore, in Zambia, most

TABLE 4 Odds ratios for the risk of malnutrition among the participants.

Variables	Adjusted OR (95% CI)	P-value*
Body mass index		
Normal	Reference	
Overweight or obese	2.44 (1.25–4.77)	0.009
Oral health		
Poor	Reference	
Adequate	4.43 (2.28–8.58)	<0.001
Depression		
Normal	Reference	
Depressed	0.21 (0.11–0.42)	<0.001
Eating disorders		
Normal	Reference	
Has an eating disorder	0.27 (0.11–0.62)	0.002
Comorbidities		
Healthy	Reference	
Peripheral vascular disease	0.13 (0.03–0.60)	0.009
Healthy	Reference	
Asthma	0.41 (0.17–0.97)	0.04
Healthy	Reference	
Diabetes	0.74 (0.43–1.28)	0.28
Healthy	Reference	
Hypertension	0.26 (0.14–0.47)	<0.001

*P-values were calculated using logistic regression adjusted for age, body mass index, and marital status, depending on the variable analyzed.
OR, odds ratio; CI, confidence interval.

older adults were found to have a low HDD and a poor nutritional status (66).

The risk of malnutrition may increase in older individuals who have at least one chronic disease, such as respiratory disease, arthritis, stroke, depression, dementia, gastric diseases, or cancer (59, 67). Moreover, the use of medications for treating these conditions may affect the appetite and swallowing function of older people and reduce the quantity and quality of food consumption and nutrient bioavailability, thereby increasing the risk of malnutrition (59, 67). Our study reported that older adults with peripheral vascular disease, asthma, and hypertension had a significant risk of malnutrition. We also found that 55% of older Saudis were malnourished and diagnosed with hypertension, whereas studies in Algeria (60) and Bangladesh (19) reported that 39.8 and 88.9% of older people, respectively, were malnourished and diagnosed with hypertension. On the other hand, our study showed that 19.8% of the participants who were at risk of malnutrition had been diagnosed with asthma or chronic lung disease, significantly less than that reported in Bangladesh (79%) (19).

A total of 15% of the participants at risk of malnutrition had peripheral vascular disease, which is relatively high. However,

studies have indicated that diabetes and heart failure are important risk factors for peripheral vascular disease (58), and almost a half and a quarter of the older people in our study were diagnosed with diabetes and heart failure, respectively. This may explain the percentage of peripheral vascular disease in our cohort (30.6%). In a study by Saquib et al. (37), conducted in the Al-Qassim region of Saudi Arabia, the prevalence of chronic diseases including hypertension, diabetes, heart disease, asthma, ulcers, and cancer in Saudi men was 71.3, 27.3, 16.4, 9.7, 8.9, and 2.0%, respectively. The participants in our study were relatively young (68.8 ± 8.7 years) based on the WHO definition of the young-old (60–74 years) (58); this group is usually healthy and independent. Furthermore, this study excluded participants with feeding tube and physical disabilities, as well as those who were admitted to hospitals or in-care institutions. Nevertheless, the prevalence of several diseases, such as asthma or chronic lung disease, Alzheimer's disease or dementia, hypertension, and depression, was relatively high in our study compared with studies conducted in other countries.

Regarding mental health status, the frequency of Alzheimer's disease or dementia and depression was relatively low in our study (9.3 and 17.6%, respectively). A Swedish systematic review reported that 1.5% and 35% of older people aged 64–69 and 90–94 years, respectively, have dementia and are at risk of malnutrition (68). Furthermore, our results showed an association between depression and the risk of malnutrition among older people; this association was more significant in those aged ≥80 years (mild depression) than in those aged <80 years (normal depression status). Similarly, Iranian (69) and Bangladeshi (19) studies have confirmed that malnutrition is significantly higher among older people with depression, with further studies in Bangladesh and Japan (19, 47) reporting the odds of malnutrition among older people who are depressed to be 15.6 and 6.3 times higher, respectively, than those who are not depressed (compared with 10 times higher in our study). Furthermore, among the participants at risk of malnutrition in our study, men tended to be less depressed than were women, which is in agreement with 69 among the 85 studies included in a review by Girgus et al. (70). Mantzorou et al. (71) also concluded that malnutrition is more common in older people who have cognitive decline and depressive symptoms. These results may be explained by the effect of depression on appetite and eating behaviors (69).

A health care system aimed at the older population has been developed in various countries. In European countries, the WHO has been working with governments to establish five priority intervention strategies: the prevention of falls and infectious diseases, promotion of physical activity, support for home care, and capacity building among health and social care workers (72). In Saudi Arabia, the Ministry of Health has established "The Home Care Program for Older Adults" to oversee all home medical services (73). Consequently, all stakeholders were required to contribute to developing policies, programs, and interventions for healthy older adults to maintain independence and remain as active as possible (74). In general, these health care systems can help to improve the health of older adults and reduce the occurrence of malnutrition in Saudi Arabia.

TABLE 5 Frequency of comorbidities stratified by nutritional status.

Comorbidities	Malnourished (n = 36)	At risk of malnutrition (n = 146)	Normal nutritional status (n = 89)	P-value*
Myocardial infarction	7 (19.4)	21 (14.5)	7 (7.9)	0.15
Congestive heart failure	11 (30.6)	25 (17.2)	9 (10.1)	0.02
Peripheral vascular disease	11 (30.6)	16 (11)	2 (2.2)	<0.001
Cerebrovascular disease	4 (11.1)	4 (2.8)	1 (1.1)	0.01
Hemiplegia or paraplegia	1 (2.8)	2 (1.4)	0	0.36
Asthma or chronic lung disease	13 (36.1)	23 (15.9)	8 (9)	<0.001
Diabetes without chronic complications	19 (52.8)	62 (42.8)	36 (40.4)	0.44
Renal disease, severe	1 (2.8)	5 (3.5)	3 (3.4)	0.86
Liver disease, moderate to severe	6 (17.1)	9 (6.2)	1 (1.1)	0.02
Peptic ulcer disease	17 (47.2)	23 (16)	10 (11.2)	<0.001
Alzheimer's disease or dementia	11 (30.6)	6 (4.1)	2 (2.2)	<0.001
Rheumatic disease	12 (33.3)	20 (14.1)	9 (10.1)	0.004
HIV or AIDS	2 (5.6)	2 (1.4)	0	0.06
Hypertension	26 (74.3)	74 (51.7)	25 (28.1)	<0.001
Peripheral skin ulcer	9 (25)	9 (6.3)	2 (2.2)	<0.001
Depression	14 (41.2)	18 (12.4)	3 (3.4)	<0.001
Cancer	2 (5.7)	6 (4.2)	0	0.11

*P-values were calculated using the Chi-square test.
Data are presented as n (%).
HIV, human immunodeficiency virus; AIDS, acquired immunodeficiency syndrome.

This study has several limitations. Despite the importance of socioeconomic level in terms of nutritional status, factors including economic status, educational level, and urban-rural were not assessed in this survey. Data on food intake, clinical signs, and laboratory investigations were also not collected to determine other factors of malnutrition. Furthermore, participants were from the Makkah region of Saudi Arabia, which limits the generalizability of the findings to the whole Kingdom. Further studies with larger sample sizes that recruit participants from all regions of Saudi Arabia are required to verify our findings. Moreover, the current study used convenience sampling which is a non-probability sampling method that might introduce selection bias, as those who were engaged in the research matter might have been more interested in participating. Nevertheless, this study is one of the few focused on the factors associated with nutritional status in Saudi Arabia, which is its the main strength. Another strength of this study is the use of several validated questionnaires, and the fact that anthropometric indices (weight and height) were measured and not self-reported. Additionally, there is a lack of research focusing on the nutritional and health statuses of older people globally, and particularly in Saudi Arabia, which highlights the importance of this study. Our findings can help to develop strategies to improve nutritional status and prevent malnutrition among older people, thereby reducing treatment costs.

5. Conclusion

Our study is one of the few studies assessing the factors associated with the nutritional status of older people, especially in Saudi Arabia. It can be concluded that there is a high proportion of malnutrition in the older population of the Makkah region of Saudi Arabia. The majority of older people of both sexes were overweight or obese, with a high risk of malnutrition. Oral health, depression, and eating disorders were factors related to the nutritional status of older people in Saudi Arabia. Among individuals with malnutrition, there was a significantly higher prevalence of peripheral vascular disease, asthma or chronic lung disease, peptic ulcers, Alzheimer's disease or dementia, hypertension, and depression than among individuals at risk of malnutrition and those with a healthy nutritional status. Generally, older people and their caretakers did not recognize symptoms of malnutrition in the early stages. Therefore, they did not seek treatments such as modified food or supplements until several conditions and complications had developed. The risk of malnutrition among older people in Saudi Arabia and globally can be reduced by regular nutritional screening and subsequent designing of nutritional interventions for timely treatment to prevent complications. The factors related to malnutrition among older people in Saudi Arabia should be studied in the future due to the increased proportion of this age group in this population group.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Biomedical Ethics Research Committee of King Abdulaziz University (Reference No. 503-21). The patients/participants provided their written informed consent to participate in this study.

Author contributions

Conceptualization: MA. Methodology: MA and IS. Formal analysis: IS. Data collection, writing—original draft preparation, reviewing, and editing of the manuscript: MA, IS, NAlm, and NAlj. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

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

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Rural-urban disparities in Oral Health-related Quality of Life for middle-aged and older adults with diabetes in Taiwan

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Background: Public health faces a significant challenge in reducing rural−urban disparities in diabetes. Since dietary control is part of the medical regimen for diabetes management, how diabetic patients perceive the impact of oral health on their quality of life is critical. The present study aimed to compare the Oral Health-related Quality of Life (OHRQoL) between rural and urban diabetic patients.

Methods: The study design was cross-sectional. The study sample included 831 self-reported diabetic patients, extracted from the first wave of the new-cohort Taiwan Longitudinal Study on Aging survey (NC_TLSA) that comprised a nationally representative sample of community-dwelling adults aged 50 and above in Taiwan. The composite score generated from the Oral Health Impact Profile-7 (OHIP-7), which has seven questions, was used to construct two OHRQoL measures, the severity of perceived poor OHRQoL and the prevalence of poor OHRQoL. These two OHRQoL measures were treated as dichotomous variables. Multivariate logistic regression models were applied for analysis.

Results: Rural diabetic patients had a higher likelihood of experiencing the severity of perceived poor OHRQoL than those in urban areas (OR = 2.40, 95% CI: 1.30−4.40). Although rural diabetic patients also had a higher prevalence of poor OHRQoL than urban diabetic patients, the difference was not significant (OR = 1.47, 95% CI: 0.95−2.28). Social determinants, such as education, are essential factors attributed to both OHRQoL measures.

Conclusion: Overall, rural diabetes community-dwelling patients had a poorer OHRQoL than those in urban areas. Given a bidirectional relationship between oral health and diabetes, improving oral health in rural areas may be a critical avenue to improve the quality of diabetes care in rural areas.

Introduction

Oral health is critical to overall health. Based on Locker's conceptual framework, poor oral health leads to physical and psychosocial health problems (1). For example, with poor oral health conditions, individuals experience pain, cannot enjoy food due to chewing difficulty, and lose interest in socialization and networking due to poor pronunciation or bad breath. Following Locker's concept, Slade and Spencer developed the Oral Health Impact Profile (OHIP) to measure Oral Health-related Quality of Life (OHRQoL), which evaluates how patients perceive the impact of oral health on their quality of life in seven domains: functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap (2). Frequent visits to the emergency department due to poor oral health highlights the impact of oral health on overall health and wellbeing (3).

For diabetic patients, oral health is even more crucial. Dietary control is part of the medical regimen to stabilize blood sugar and reduce the likelihood of diabetes-related complications (e.g., blindness due to retinopathy). Poor oral health would limit food choices and increase the difficulty for diabetic patients in managing their daily life. Most importantly, there is a causal relationship that runs both ways between diabetes control and oral health conditions (4). Diabetic patients are more likely to develop different forms of oral health problems, such as periodontal disease, dry mouth, and dental caries, and to develop few remaining natural teeth than those without diabetes (5, 6). Diabetic patients with poor oral health also have poorer diabetes control due to insulin resistance than those without poor oral health (7, 8), which increases the likelihood of having diabetes-related complications. As the prevalence of diabetes among individuals aged 20–79 years is expected to increase from 9.7% in 2021 to 12.6% in 2045 (9), oral health for diabetes patients is regarded as a critical issue from the perspective of public health.

Although several studies investigated clinical dental problems for diabetic patients, only a few focused on self-reported quality of life. Some studies measured general health quality of life, such as the number of physically and mentally unhealthy days (10). Others used OHIP to measure OHRQoL. Previous studies examined the impact of periodontal diseases on the OHRQoL between patients with and without diabetes and found mixed findings (11–13). Others identified risk factors associated with the poor OHRQoL of diabetic patients and found several risk factors, including, but not limited to, dry mouth sensation, the use of a removable prosthesis, untreated dental caries, periodontal disease, unmet denture needs, low income, and poor oral hygiene (14, 15). Based on the national data with a sample of 2,945 community dwellers in the United States, the study found that diabetic patients were more likely to experience poorer OHRQoL than those without diabetes (15).

There is a rural–urban discrepancy in diabetes incidents and diabetes-related complications. Compared to the urban population, rural individuals are at a higher risk of having diabetes, receive poorer process of diabetes care (e.g., high blood pressure and hemoglobin A1c), and have poorer outcomes (e.g., nephropathy, low-extremity amputation, and mortality) (16–20). In addition, there is a rural–urban disparity regarding oral health conditions. Rural populations generally have higher periodontal disease and tooth decay rates, with fewer remaining natural teeth and receiving less preventive dental care than urban populations (21, 22). A study based on the general population in Quebec, Canada found that rural community dwellers had poorer OHRQoL than those who resided in urban areas (23). Given the discussion above, one would expect a rural–urban discrepancy regarding the OHRQoL among diabetic patients. However, to the best of our knowledge, evidence regarding discrepancies in OHRQoL of diabetic patients due to rurality is lacking. Diabetes and oral health are the top priorities for improving rural population health (24, 25). Evidence regarding OHRQoL for diabetic patients in rural areas would help policymakers find strategies to improve rural population health.

The present study aimed to compare the difference in OHRQoL between rural and urban diabetic patients by using the national data of Taiwan. Approximately 20% of the Taiwanese population reside in rural areas (26), similar to some developed countries, such as the United States (27). In 1995, Taiwan implemented a single-payer universal health insurance program that covered 99% of the Taiwanese population with low-cost healthcare (28). However, nearly 30 years later, rural–urban disparities in diabetes and oral health care remain (18, 19, 29). Empirical evidence from the present study fills the existing literature gap and provides direction regarding how to deliver better care to people in rural communities.

Materials and methods

Data source

The primary data source of the present study is the first wave of the new-cohort Taiwan Longitudinal Study on Aging survey (NC_TLSA), which the Taiwan Health Promotion Administration, Ministry of Health and Welfare launched in 2015. The NC_TLSA comprised 5,304 individuals, a nationally representative sample of community-dwelling adults aged 50 and above, with a response rate of 70.7% (30). The survey questions include six dimensions: (a) personal information, marriage status, and residence history; (b) household structure, satisfaction with a living arrangement, and interaction with children, relatives, and others; (c) health status, health utilization, and hygiene behaviors; (d) social support and exchange; (e) work history; and (f) social participation and physical safety (30). The data were collected through face-to-face interviews. TLSA provides variables necessary for the present study, such as the Oral Health Impact Profile (OHIP) commonly used to assess OHRQoL, the diseases that individuals had, and the locations where individuals lived at the time of the interview. The sampling process, survey questions, and data validity of the NC_TLSA are available on the TLSA website (30).

Study design and study sample

The study was cross-sectional, with community-dwelling adults aged 50 and older who self-reported having diabetes as the study
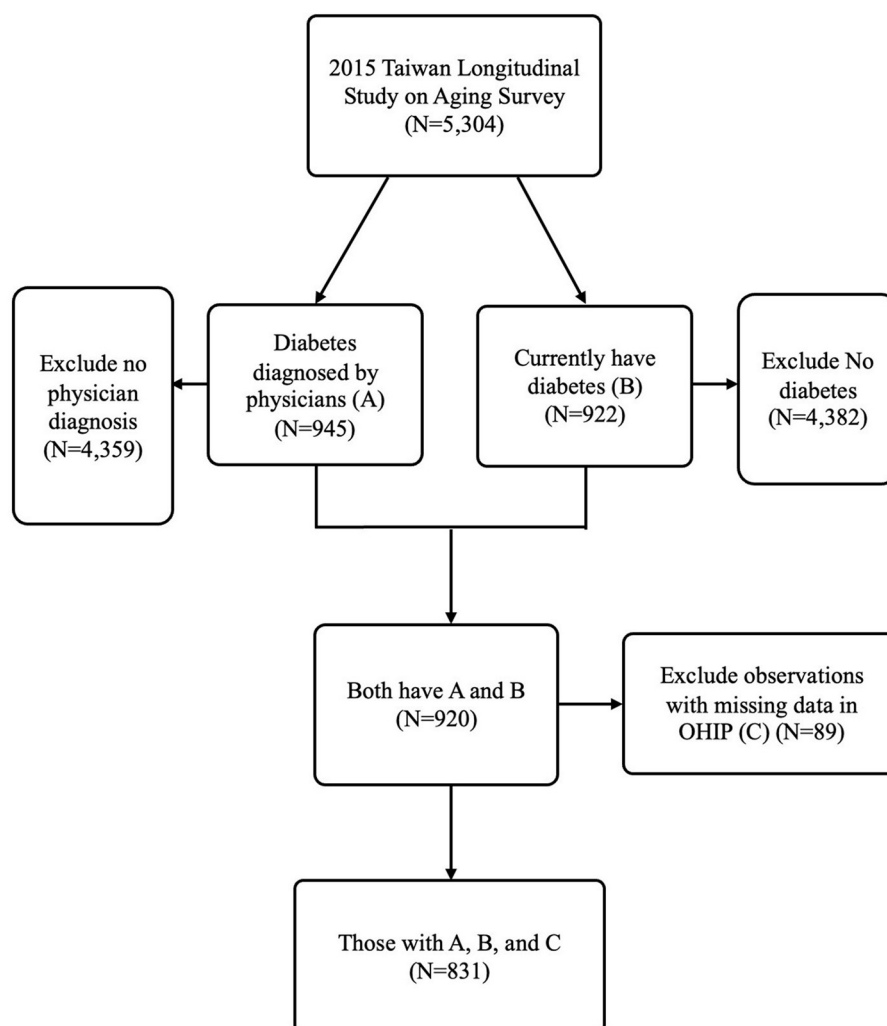
sample. The TLSA had two questions. One is, "Have you ever been told by a doctor that you have diabetes?" The other is, "Do you still have the disease at the time of the interview?" Individuals who answered "yes" to both survey questions were defined as having self-reported diabetes in the present study. In total, 920 individuals answered "yes" to both questions. The present study further excluded 89 individuals with missing OHIP data. The final qualified study sample was 831 community-dwelling diabetic patients in the present study. Figure 1 presents the selection process for the study sample.

Variable measures

Dependent variables

OHRQoL, the primary outcome variable of interest, was assessed by the OHIP-7. The original OHIP has 49 survey questions (OHIP-49). Later, the number of questions from the OHIP-49 was

shortened into different versions (e.g., OHIP-14 with 14 questions and OHIP-7 with seven questions) and used in other countries.

OHIP-7—a validated Mandarin version of OHIP in NC_TLSA (31), which had been used in a previous study (32, 33)—surveys individuals' experiences related to teeth or denture problems in the past 12 months at the time of the interview through seven questions: (1) "Have you ever been aware of teeth or dentures problems?", (2) "Have you ever been interrupted in a meal because of teeth or dentures problems?", (3) "Have you ever experienced discomfort while eating because of teeth or dentures problems?", (4) "Have you ever had difficulties with concentration because of teeth or dentures problems?", (5) "Have you ever experienced difficulties with pronunciation because of teeth or dentures problems?", (6) "Have you ever confronted difficulties with performing daily life because of teeth or dentures problems?" and (7) "Have you sensed taste deterioration because of teeth or dentures problems?". Each survey question was rated on a 5-point Likert scale (never = 0, rarely = 1, occasionally = 2, often = 3, and very often = 4). The Likert scale from the seven survey questions

was used to construct a composite score to assess how frequently individuals experienced poor OHRQoL.

Following previous studies (15, 23), the composite score generated from OHIP-7 was used to construct two OHRQoL measures—the severity of perceived poor OHRQoL and the prevalence of poor OHRQoL. The severity of perceived poor OHRQoL was based on a summative score, ranging from 0 to 28, generated from seven questions in OHIP-7. A higher score means a poorer OHRQoL. The summative score was then categorized as a dichotomous variable using the 85th percentile as a cutoff point (a score ≥8 was coded as one and zero otherwise), which was commonly used in the previous study (15). The prevalence of poor OHRQoL is the percentage of individuals rated "often" or "very often" for one or more questions in OHIP-7. The prevalence of poor OHRQoL was also dichotomized. Individuals who rated "often" or "very often" for at least one question in OHIP-7 were coded as one and zero otherwise (15, 23).

Key independent variable

The key independent variable of interest is the place of residence, categorized as rural and urban (urban as the reference group). TLSA provides five categories of residential areas: metropolitan, any major city at the province and county levels, towns, and rural areas. Individuals who lived in rural areas were coded as one and zero for those in urban areas as the reference group.

Control variables

The present study chose covariates based on the Andersen Behavioral Model of Health Care Utilization, focusing on the association between health outcomes and individuals' predisposing, enabling, and health need factors (34). Predisposing factors included a series of dummy variables, including age (50–64 and 65+ years), sex (men and women), and marital status (married and others, such as single or divorced). Enabling factors included dichotomous variables: employment status (with or without a job), education (with or without a high school diploma), living status (living alone or not), and family/social support (satisfaction or no satisfaction with family or social support). Finally, health need factors included two dummy variables: (1) functional condition (with or without at least one difficulty in the activity of daily living (ADL) or instrument activity of daily living (IADL)) and (2) poor health behaviors (with or without having behaviors related to drinking, smoking, or chewing betel), as well as a count variable for the number of comorbidities.

Analytical approach

The present study applied the bivariate analyses by using a t-test and the chi-squared test to compare the differences in study variables between rural and urban community-dwelling diabetes patients. Because the severity of poor perceived OHRQoL and the prevalence of poor OHRQoL were dichotomous, the present study applied multivariate logistic regression models to test the hypotheses. The odds ratio and 95% confidence intervals were reported with the significant level defined as a P-value of <0.05.

The odds ratio higher than one means a higher likelihood of experiencing poor OHRQoL. The SAS version 9.4 was applied for the analyses.

Results

Figure 1 shows the study sample selection process from national survey data based on the middle-aged and older population (TLSA). Approximately 17% of the self-reported middle-aged and older populations have diabetes and received diagnosis from physicians. The prevalence of diabetes in TLSA is higher than that reported among the population aged 20–79 years from the IDF Diabetes Atlas of Taiwan in 2021 (9). However, another study showed that the prevalence of diabetes was ~40% among the older adults in 2014 (35). The percentage of diabetes patients (17%) in our study falls within the range of the prevalence in these two previous studies (9, 35), indicating that the prevalence of diabetes among the middle-aged and older populations in our study is reasonable.

Table 1 compares the differences in the severity of perceived poor OHRQoL, the prevalence of OHRQoL, and control variables relative to predisposing, enabling, and health needs between rural and urban diabetic patients. The severity of perceived poor OHRQoL among rural diabetic patients is ~24%, while among urban diabetic patients, it is ~16% (P < 0.05). The prevalence of OHRQoL among rural diabetic patients was ~30%, while among urban diabetic patients, it was ~21% (P < 0.05). There was no significant difference regarding the predisposing (e.g., age and sex) and health need factors (AD:/IADL). However, compared to urban diabetic patients, rural diabetic patients had a higher rate of not having a high school diploma (86.47% for rural patients vs. 68.77% for urban patients) and were living alone (13.53% for rural patients vs. 7.88% for urban patients).

Table 2 presents the adjusted differences in the severity of perceived poor OHRQoL and the prevalence of poor OHRQoL between rural and urban patients after controlling for the covariates of the predisposing (e.g., age and sex), enabling (e.g., education and employment status), and health need factors (e.g., comorbidities and living alone). Regarding the severity of poor perceived OHRQoL, rural diabetic patients had a higher likelihood than urban diabetic patients (OR: 1.65, 95% CI: 1.02–2.68). Regarding the prevalence of poor OHRQoL, rural diabetic patients had a higher likelihood than urban diabetic residents; however, the difference was not significant (OR: 1.47, 95%CI: 0.95–2.28).

Education and ADL/IADL limitations are most notable among all covariates because they are significantly associated with both poor OHRQoL measures. For example, diabetic patients with a high school diploma or above had a lower likelihood of experiencing the severity of perceived poor OHRQoL (OR: 0.60, 95%CI: 0.36–1.00) and a lower prevalence of poor OHRQoL (OR: 0.53, 95% CI: 0.33–0.83) than their counterparts. However, the difficulty in performing at least one ADL/IADL limitation is significantly associated with the severity of perceived poor OHRQoL (OR: 3.09, 95%CI 1.97–4.87) and the prevalence of poor OHRQoL (OR: 2.10; 95%CI: 1.40–3.15) Furthermore, those living alone were more likely to experience the severity of perceived poor OHRQoL than those without (OR: 1.94, 95%CI: 1.06–3.57). Finally, individuals who

TABLE 1 Comparison of control variables between rural and urban community-dwelling diabetic patients.

Study variables	Rural (N = 133)	Non-rural (N =698)	χ^2/t
Dependent variables			
The severity of perceived poor Oral Health-related Quality of Life	32 (24.06%)	109 (15.62%)	5.65*
Prevalence of poor Oral Health-related Quality of Life	40 (30.08%)	145 (20.77%)	5.58*
Pre-disposing factors			
Age			0.05
50–64	62 (46.62%)	333 (47.71%)	
65+	71 (53.38%)	365 (52.29%)	
Sex			0.15
Male	65 (48.87%)	354 (50.72%)	
Female	68 (51.13%)	344 (49.28%)	
Marital status			2.17
Married	83 (62.41%)	481 (68.91%)	
Single, devoice, separate, or widow	50 (37.59%)	217 (31.09%)	
Enabling factors			
Employment status			3.67
Employed	51 (38.35%)	209 (29.94%)	
Unemployed	82 (61.65%)	489 (70.06%)	
Education status			17.21***
With a high school diploma or above	18 (13.53%)	218 (31.23%)	
Without a high school diploma	115 (86.47%)	480 (68.77%)	
Living status			4.46*
Living with someone	115 (86.47%)	643 (92.12%)	
Living alone	18 (13.53%)	55 (7.88%)	
Family/social support			0.98
Satisfied	117 (87.97%)	590 (84.65%)	
Unsatisfied	16 (12.03%)	107 (15.35%)	
Health needs			
Activities of daily living or Instrumental activities of daily living limitations			0.08
None	98 (73.68%)	506 (72.49%)	
At least one difficulty	35 (26.32%)	192 (27.51%)	
Comorbidities[a]	1.83 (1.41)	1.79 (1.41)	0.74
Unhealthy behaviors related to drinking, smoking or chewing betel			0.13
None	18 (13.53%)	103 (14.76%)	
At least one unhealthy behavior	115 (86.47%)	595 (85.24%)	

[a] Mean and standard deviation in the parenthesis, with t value for the comparison; *P < 0.05.

were satisfied with support from relatives and friends had a lower likelihood of experiencing the severity of perceived poor OHRQoL than those who were not (OR: 0.51, 95%CI: 0.31–0.83).

Discussion

In summary, the present study found that rural diabetic patients had a higher severity of perceived poor OHRQoL than urban diabetic patients, with a statistical significance. Rural diabetic patients also had a higher prevalence of poor OHRQoL than urban diabetic patients, although the difference was not significant. Dietary control, regular exercise, and medication adherence form a three-leg medical regimen for diabetes control. Reasonable dietary control requires a healthy oral condition to chew and enjoy various foods while obtaining nutrition and maintaining blood sugar in good condition. With poor perceived OHQRoL, such as meal interruption and discomfort while eating due to

TABLE 2 Difference in poor Oral Health-related Quality of Life between rural and urban diabetic patients (N = 831).

Study variables	Severity of perceived poor OHRQoL, OR (95% CI)	Prevalence of poor OHRQoL, OR (95% CI)
Key independent variable		
Rural (ref = Urban)	1.65* (1.02–2.68)	1.47 (0.95–2.28)
Control variables		
Predisposing factors		
aged 65 and above (ref = aged 50–64)	0.83 (0.53–1.31)	1.19 (0.80–1.78)
Female (ref = male)	0.81 (0.51–1.29)	0.85 (0.56–1.28)
Married (ref = single, devoice, separation, or widow)	0.68 (0.44–1.06)	0.67* (0.45–1.00)
Enabling factors		
Having a job (ref=unemployment)	0.76 (0.44–1.30)	1.05 (0.66–1.68)
High school diploma or above (ref = without a high school diploma)	0.60* (0.36–1.00)	0.53** (0.33–0.83)
Living alone (ref = living with someone)	1.94* (1.06–3.57)	1.40 (0.79–2.50)
Satisfied with support from relatives and friends(ref = unsatisfied)	0.51** (0.31–0.83)	0.94 (0.58–1.51)
Health needs		
At least one ADL or IADL limitation (ref = No ADL or IADL issue)	3.09*** (1.97–4.87)	2.10*** (1.40–3.15)
Number of comorbidities	1.06 (0.92–1.21)	1.15* (1.01–1.30)
Health behaviors related to drinking, smoking or chewing betel (ref = No)	1.65 (0.88–3.12)	1.11 (0.66–1.88)

*P < 0.05, **P < 0.01, ***P < 0.001.

teeth and denture problems, patients are likely to experience poor functions for food intake, which would increase the challenges of diabetes management.

Taiwan has implemented a single-payer system under a universal health insurance program since 1995. The program provides comprehensive health care coverage, including inpatient and outpatient western medicine, Chinese medicine, and dental and vision care to the population in Taiwan at a low cost. However, access to dental care for rural residents is still challenging due to the difficulty in recruiting and retaining the healthcare workforce in rural areas in Taiwan. As a result, rural individuals had lower dental utilization and fewer numbers of natural teeth than urban individuals (29, 36), which may explain the findings in the present study.

In addition to geographic factors, other social determinants also affect OHRQoL. Consistent with past findings (35, 36), this analysis shows that social support is critical for chronic disease patients and dental utilization, which would improve the OHRQoL for diabetic patients. In addition, individuals with low health literacy were associated with poor oral health conditions (37). Our findings showed that diabetic patients with a high school diploma and above were less likely to experience poor OHRQoL than those without a high school diploma. Furthermore, evidence showed misconceptions about oral health in the rural population in Taiwan (38). In our study sample, ~86% of diabetic patients in rural areas did not have a high school diploma, and the low education level probably contributes to the misconception. Hence, it is crucial to provide oral health education for rural diabetic patients.

Furthermore, diabetic patients having at least one ADL or IADL limitation were at a higher risk of poor OHQRoL in both measures than those without ADL or IADL limitations. Our findings are consistent with the findings in the literature. Based on Japanese older patients living with family, the study showed that ADL was related to poor OHQRoL (39). Furthermore, a longitudinal study conducted in England, which tracked individuals for two decades, found that the number of natural teeth prevented individuals from losing IADL capacities (40). The above evidence indicated a potential bilateral relationship between poor oral health conditions and ADL or IADL limitations.

Limitations

The present study has some limitations. First, the rurality was defined by the residential location of individuals who received an interview at the time. Given a cross-sectional study, we could not know the length of time the individuals lived in rural areas. In addition, based on a cross-sectional study design, we were not able to track the change of OHQRoL for individuals from time to time or identify the causal relationship between diabetes and ORQRoL. In addition, diabetic patients included in the study (with OHIP data) were younger and had fewer ADL/IADL limitations than those excluded (without OHIP data). Therefore, the generalizability of the findings in the present study to other populations must be cautious. Finally, the number of dentists or primary care physicians per 1,000 population is likely associated with access to oral health; however, NC_TLSA does not provide residential areas, making merging with other data impossible.

Despite the limitations discussed above, our findings provide implications for policies and future research. The impact of oral health on diabetes control and other chronic conditions was documented decades ago (7, 8). However, policies that address integrating oral health care into primary care practice are largely ignored in Taiwan. In 2001, Taiwan implemented a diabetes pay-for-performance program that financially motivated physicians if their patients received a list of recommended exams, such as an eye exam and hemoglobin A1c. As a result, rural–urban disparities in recommended exams were reduced (41), indicating that healthcare providers responded to payment incentives. However, the diabetes pay-for-performance program does not include dental referrals or assessments as part of quality performance measures. As diabetes control and oral health affect each other (7, 8), providing financial incentives for a dental referral or assessment for diabetes care through the payment system would help diabetic patients receive dental care and further reduce rural-urban disparities in OHRQoL in the future. For example, in 2014, the Department of Health and Human Services Administration in the United States launched interdisciplinary collaboration between dentists and primary care practitioners through meaningful information exchange, referral, and patient/population-centered care (42). The policy facilitated clinics to refer patients to dentists or to include oral health assessment at the primary care clinics, especially those in rural or underserved areas (43). Furthermore, oral health education at the early-stage of childhood, any stage of adulthood, or during follow-up physician appointments is critical to enhancing self-oral health care. Finally, the present study found that rural patients experienced the severity of poor perceived OHRQoL. Future studies that investigate the impact of poor OHRQoL on diabetes control and diabetes-related complications are recommended.

Conclusions

Oral health and diabetes are both listed as top priorities for improving rural population health (44). Overall, rural diabetic patients had a poor OHQRoL than those in urban areas. Given the bidirectional relationship between oral health and diabetes control, improving oral health in rural areas may serve as a critical avenue to improve the quality of diabetes care in rural areas.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: The datasets used and analyzed in the present study are not publicly available but are available from the corresponding author on reasonable request with the permission of the Ministry of Health and Welfare, Taiwan. Requests to access these datasets should be directed to chenhf@kmu.edu.tw.

Ethics statement

The study was approved by the Institutional Review Board at Kaohsiung Medical University Hospital in Taiwan (KMUHIRB- E(I)-20210211).

Author contributions

HFC conceptualized the study, obtained funding, designed the study, conducted a quality check, wrote the first draft of the manuscript, and revised the manuscript. YTL conducted a literature review, analyzed the data, interpreted the findings, and reviewed and revised the manuscript. JYL conducted a literature review, managed administration for the project, prepared tables, and reviewed and revised the manuscript. HEL conceptualized the study, designed the study, interpreted the findings, supervised the project, and reviewed and revised the manuscript. All authors have read and approved the final version of the manuscript.

Conflict of interest

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

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The influence of strong social ties on the choice of long-term care model for middle-aged and older adults in China

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With the acceleration of population aging in China, the care of middle-aged and older adults has become the focus of social attention. As China is an "acquaintance society," strong social relations play an important role in residents' access to information and resource allocation, which has an impact on the choice of long-term care models for middle-aged and older adults. Therefore, based on the 19,728 samples from the 2018 CHARLS Phase I data, an empirical analysis was conducted using a logistic dichotomous model, which showed that both kinship (p <0.01) and friendship (p<0.01) among social relationships positively influenced the choice of social care models for middle-aged and older adults. The analysis of the heterogeneity showed that the choice of long-term care models was significantly influenced by strong social relationships in the central and western regions and rural areas (p <0.01). On the basis of this, the transmission mechanism of strong social relationships was further analyzed in conjunction with the further construction of the SIRS Contagion Model, which was used to describe the information transmission process. The results showed that residents who attached importance to strong social ties were more likely to incur medical transfer expenditure, thus further increasing their own demand for the formal care model. The policy implications of this study are to promote the coordinated development of long-term formal care and strong social relations, to further promote the socialization of the formal care model while relying on traditional family care, and to build a multi-level and diversified long-term care system for middle-aged and older adults.

KEYWORDS

China, strong social relationship, population aging, long-term care, SIRS Contagion Model

1. Introduction

At present, China's aging population is growing rapidly and the number of senior citizens is increasing sharply (see Figure 1). According to the results of the seventh national census, by the end of 2020, China had 260 million people aged 60 and above, accounting for 18.70% of the total population. Among them, the proportion of people aged 65 or above reached 13.50%, an increase
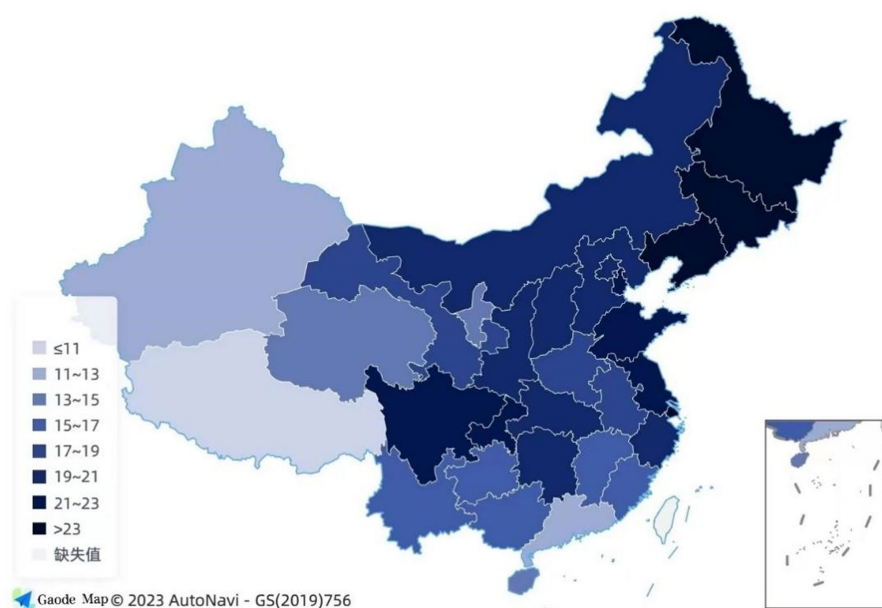
FIGURE 1
The proportion of older adults aged 60 and above in each province of China.
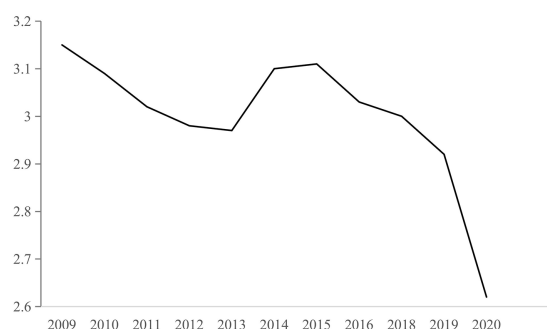
FIGURE 2
Trends in household size in China.

of 2.51 and 2.72 percentage points[1] compared with 2010. At the same time, the rate of disability among older adults has also risen sharply. The survey showed that the number of older adults with disabilities has exceeded 42 million, with about one in every six older adults unable to take care of themselves.[2] In recent years, the family structure tends to be smaller, with fewer children[3] (see Figure 2), and the dependency ratio of the older adult population has risen to 19.70%. In one interview about older adults, a child of older adults said: "The older adult in the family

have changed from cheerful to introverted after becoming disabled, believing that caring for themselves has put pressure on their children, and have even thought of committing suicide." Due to the rising rates of disability and senior support, such problems have gradually attracted extensive social attention. How to properly deal with the failure of care of middle-aged and older adults in China has become one of the "hot" issues.

In the face of the heavy care problems of the aging society, social home care, institutional care, and other formal care methods continue to rise, but overall older adult care still presents a "9,073" pattern.[4] In recent years, China has issued a series of long-term care systems and policies for middle-aged and older adults: in 2016, China has implemented long-term care trial projects in Qingdao, Nantong, and other locations to better address the demands of day care for older adults with disabilities. In 2019, the Chinese government issued the Medium and Long Term Plan for National Active Response to Aging Population, which set the goal of "building high-quality supply of older adults care services."[5] In 2020, the state again promulgated the Guiding Opinions on Expanding the Trial of the Long-term Care Insurance System to further expand the scope of the trial on the basis of the original pilot cities. In November 2021, the State Council of the People's Republic of China issued the Opinions on Strengthening

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1   National Bureau of Statistics of China. *The Seventh National Population Census.* [EB/OL]. http://www.stats.gov.cn/ztjc/zdtjgz/zgrkpc/dqcrkpc/.

2   China Aging Working Committee Office. The survey of disabled elderly in *the Survey Report on the Living Conditions of Urban and Rural Elderly People in China (2018).*

3   CEIC. http://www.ceicdata.com/zh-hans/china/population-no-of-person-per-household.

4   The "9,073" elderly care pattern refers to that about 90% of the elderly live at home, 7% rely on community support for elderly care, and 3% live in institutions for elderly care.

5   Department of Aging Health of the National Health Commission of the People's Republic of China. Policy interpretation of *the Guiding Opinions on Establishing and Improving the Health Service System for the Elderly.* [EB/OL]. http://www.nhc.gov.cn/lljks/s7786/201911/4cbecd7450694416a181f9b37e92.shtml,2019.11.01.

Work on Aging in the New Era, proposing to improve the old-age service system and strengthen long-term care services and security for older adults with disabilities.[6] Although the long-term care system has made certain achievements in China, the development of socialized and diversified long-term care services still has a realistic dilemma. From the perspective of traditional culture, Confucianism has been rooted in our social structure for a long time and the traditional family pension model with "raising children for the old" as the main concept is the mainstream position (1). However, with the continuous improvement of economic levels, household sizes are shrinking and the smaller family structure of "421"[7] makes the traditional family pension model difficult to sustain. A socialized formal care model that can address the issues of population aging and aging disability should be introduced in this situation (2).

In the face of the increasingly diversified care model, how middle-aged and older adults choose what kind of care model is affected by many factors. Among them, social attributes cause people's behaviors to be affected by the surrounding environment (3). Jinhua Liu (4) points out that the economic behaviors of residents in a group will be affected by others' behaviors due to social interaction. China, as a relational society, has formed a social network with kinship, geography, and trust as the core for thousands of years. It is an important hub in the process of information acquisition and resource allocation, and exerts an important influence on individual economic decision-making. In the social network, the relationships that mainly affects individual behavior are called "strong social relationships," and are composed of kinship and friendship. So, how do strong social ties influence the choice of long-term care patterns among middle-aged and older adults? What is the influence of different types of strong social relations on the long-term care patterns of middle-aged and older adults? In view of the above questions, this study uses the 2018 data of the China Health and Retirement Longitudinal Study (CHARLS) to explore the influence of strong social ties on the choice of care models of middle-aged and older adults in China. On a theoretical level, the paper investigates how certain social characteristics of an individual may affect their choice of long-term care setting and makes an attempt to explain how this can be the case. On the practical level, based on the theory and empirical results, this study proposes corresponding policy suggestions for the development of formal care patterns in order to further popularize social care and enhance China's senior disability care system.

The structure of the rest of this study is as follows: the second section reviews the existing literature and puts forward the theoretical basis and research hypothesis. The third section describes the data sources, research samples, and statistical models. The fourth section includes descriptive statistics, regression analysis, robustness tests, and heterogeneity analysis of variables. Finally, the last section is the summary and recommendations.

2. Theoretical basis and research hypothesis

2.1. Theory of strong social relations

A social network, or social relationship network, was first proposed by Radcliffe Brown, who believed that a social network is a kind of social relationship that allows its members to maintain intimate contacts and is a concept of social capital. Academic circles mainly interpret social capital as "actual or potential resource collection, which consists of mutual default or recognition relations" (5). Based on the concept of social capital, the definition of social capital and social networks have been derived correspondingly, but, fundamentally, the discussion is still aimed at the relationship between individuals and their groups. Mark (6) argued that individuals are not completely independent when making decisions, and the social network they are in has a certain influence on their behavioral decisions. A large number of studies have proved that the deeper an individual is embedded in the social network, the greater the possibility of social participation. Social networks can not only help families disperse certain risk impacts and smooth household consumption, but also realize a certain degree of resource sharing and reduce transaction costs. At the same time, social networks can provide certain emotional support for their members and reduce the influence of negative psychological factors through mutual communication. In the social relations theory proposed by Mark (7), the social relations of residents are mainly divided into two categories: "strong social relations" and "weak social relations." Among them, "strong social relationships" refer to the social networks with strong homogeneity and strong convergence of information exchanged between people. In China, Confucian traditional culture has exerted a far-reaching influence on social development for a long time, forming a social structure with friends and relatives as the core and an "acquaintance society" as the main feature (8). In ordinary life, families invest in strong social relationships through social interactions such as human relations or traditional customs and gatherings. For a long time without formal institutions, strong social relationships were the main channels for family members to seek help from negative impacts (9).

To sum up, strong social relations are the main social relations that affects the economic behavior of Chinese residents. Based on this, this article draws on the classification of existing literature (10) and divides strong social relations in China into the two major categories of kinship and friendship by using consanguinity, business relationships, and interest relationships as the main standards. Kinship is mainly based on consanguinity, including spouses, blood relatives, and in-laws (Article 1,045 of the Civil Code). On the other hand, friendship is based on business relationships and interest relationships, Friendship is a kind of non-blood relationship, its formation is mainly based on business and interest. In China, close friends will transfer funds such as gift money and rescue money in the process of communication (11).

2.1.1. Kinship and choice of care model for older adults

In China, Kinship based on blood has always been an important way for families to spread risks. Fei (12) proposed that traditional Chinese society is a "differential pattern" based on clan groups and the

network relationships centered on kinship. Everyone is in the center of the influence range exerted by his or her social network, and, at the same time, he/she is affiliated to the circle centered by people superior to himself/herself. Kinship implies the obligation of reciprocity, and mutual assistance is mainly carried out through gifts, loans, labor assistance, and other means, which plays a role in smoothing household expenditure and resisting family risks (13). By virtue of its reciprocity and altruism, kinship provides necessary help for the special moments in the life cycle of individuals in its social network, and has the function of risk transfer, such as the care or support services provided by kinship (14). At the same time, reciprocal and mutual assistance based on kinship can effectively deal with the problem of "moral hazards." Good kinship is one of the important indicators of character evaluation in China (15), Instead of hoping for additional benefits, residents frequently turn to kinship to minimize their losses. Therefore, under the influence of family orientation, home care, which emphasizes "raising children for old age" and "mutual assistance by relatives," has been the most important model of care for older adults in China for thousands of years. Even though the market economy and modern thinking have had a series of impacts on the traditional culture of the family (16), Chinese traditional parent–child feedback concepts of care for older adults still carries considerable weight among modern residents. Home care is still the preferred way of care for residents, and the mutual assistance and reciprocity generated by traditional kinship may have a certain substitution effect on formal care models such as institutional care.

But at the same time, kinship may have a certain positive impact on residents' choice of formal care model. Weber once proposed that the foundation of all trust in China is obviously based on kinship or purely personal kinship. Kinship has the advantage of natural high trust and has a considerable aggregation effect. Through kinship, residents can transfer and share information resources, transmit and perceive risks, which may influence purchasing decisions for formal care. Based on the above analysis, this study proposes the following hypothesis:

H1.1: Kinship has a substitution effect on the choice of institutional care for middle-aged and older adults.

H1.2: Kinship can promote the choice of institutional care for middle-aged and older adults.

2.2. Friendship and older adult care model choice

As an important part of a strong social relationship, friendship has long been embedded in traditional Chinese culture and has a profound impact on residents' economic life (17). In most existing studies, friends are defined as social relationships based on business ties and interest ties (18), which often include both ordinary friends based on interest ties, and colleagues, classmates, and friends based on business ties (19).

By virtue of its trust advantage, the information conveyed by strong social relationships is more likely to be adopted by residents (20), reducing the cost of information search and enhancing the

participation in collective behaviors. Residents have social interactions with the network of friends through human relations such as "exchange of gifts," which promote the degree of trust between them, so as to carry out high-quality information transmission and sharing. Liu and Du (21) used simulation experiments to find that disaster experiences in friends' social networks would also encourage non-disaster groups to make plans for a rainy day. According to the existing literature, the paths that friend relationship affects individual behavior can be summarized into risk perception (22), imitation, and learning (23). Among these, the risk perception pathway refers to an individual's understanding of risk information and obtaining risk perception through conversations with friends (24). Learning means that residents acquire socialized formal care information through friendship communication, learn relevant knowledge, and make choices independently (25). Imitation mainly refers to the behavior of residents simply imitating and copying a selection of peers without understanding relevant knowledge (26). Compared with other countries, formal care in China started later, and residents have relatively little understanding of the relevant information. Socialized formal care behavior transmits information in friendship through the above three paths, which may improve the participation rate of residents' formal care behavior to a certain extent. Based on this, this study proposes the following hypothesis:

H2.1: Friendship can promote older adult's choice of social care.

H2.2: Friendship has an inhibitory effect on older adult's choice of social care.

3. Research methods

3.1. Sample selection

The empirical analysis of this study is based on the 2018 data of the China Health and Retirement Longitudinal Study (CHARLS). The China Health and Retirement Longitudinal Study aims to collect a set of high-quality microdata representing the households and individuals of middle-aged and older adults aged 45 and above in China to analyze the problem of population aging in China and promote interdisciplinary research on the problem of aging. The CHARLS national baseline survey was carried out in 2011, covering 150 county-level units, 450 village-level units, and 17,000 people in about 10,000 households. By the time the nationwide follow-up was completed in 2018, the sample had covered 19,000 respondents from 12,400 households, covering 11 aspects including personal information, health status, and medical insurance services. The access response rate and data quality of CHARLS are among the top of similar projects in the world, and the data has been widely used and recognized in the academic world.

By screening the data of CHARLS in 2018, this study limited the age of the sample Chinese middle-aged and older adult groups to 45–60 years old. At the same time, individual samples with key information missing and unavailable information were eliminated. Finally, 19,728 samples with relatively complete information were

retained for empirical discussion, among which 5,698 urban samples and 14,030 rural samples were retained.

3.2. Variable description, data sources, and descriptive statistics

3.2.1. Explained variables

This study treats the use status of middle-aged and older adult's home and community care service in China as the explained variable and is expressed by care_all. According to question EH005_W4 in the 2018 CHARLS questionnaire: "Have you enjoyed the following home and community care services?," the options include "day care center, nursing home, dining table for the older adults," "regular medical check-up," "home visit," "family bed," "community care," "health management," "recreational activities," "other" and "none of the above," In this paper, the first eight options are defined as choosing home and community aged care services and coded as "1 (formal care)," and the option "None of the above" is defined as choosing informal care and coded as "0 (informal care)."

3.2.2. Explanatory variables

The core explanatory variable of this study is the strong social relations of Chinese residents. According to the two main hypotheses put forward in the theoretical basis, this study divides the core explanatory variables of strong social relations into kinship and friendship.

3.2.2.1. Kinship

The core explanatory variable of H1 hypothesis is the relative relations of Chinese residents. According to the existing research, kinship is a relatively broad concept. This study draws on the existing literature and studies 5 groups of indicators in CHARLS 2018 (27), which are: "How much financial support did you or your spouse give/receive from your parents in the past year?," "How much financial support have you or your spouse given/received from your children in the past year?," "How much financial support did you or your spouse give/receive from your siblings in the past year?," "How much financial support have you or your spouse given/received in the past year to other relatives or friends you do not live with who are not parents, children, or siblings?," and "How much money have you or your spouse given/received in the past year to other relatives or friends you do not live with who are not parents, children, or siblings?" In this paper, the variable hosnet_R is constructed by combining the above 5 groups of indicator data and processing them logarithmically. Human exchange is a Chinese custom and tradition, which is usually embodied in mutual economic support in kinship relationships. The higher the amount and frequency of economic support, the closer the kinship relationship. Therefore, the construction variable hosnet_R can reflect the real situation of kinship relationships in strong social relationships to a certain extent.

3.2.2.2. Friendship

In sociology, according to the "Granovetter theory of social relations," close friends are often regarded as strong social relations together with family members and relatives (28). The definition of

TABLE 1 KMO test results of principal component analysis.

Item	KMO	Principal component
In the past year, how much did you or your spouse spend on catering for weddings and funerals, moving to a new house, a new baby, a child going to school, etc.?	0.5157	0.5715
How many meals did your guests have at your home in the last week, per person?	0.5150	0.5804
Have you had any of the following social activities in the past month?	0.5150	0.5801
Full sample	0.5152	-

"friends" in the relevant literature is mostly based on business ties and interest ties (29). However, the scope of fun ties is relatively larger than business ties, and close work relationships are often included in the relationship of friends, which is difficult to distinguish (19). Therefore, this study defines the independent variable (friendship of Chinese residents) assumed by H2 as non-blood and non-in-law relationships based on interests or business relationships.

As the definition of friendship is relatively virtual and broad, it is difficult to measure a single index in the questionnaire. Therefore, this study refers to the practice of Wang Xiaoquan (13) and selects three indicators of CHARLS 2018 data on the basis of considering both economic factors (social spending) and non-economic factors (social frequency), which are: "How much money did you or your spouse spend on catering for weddings and funerals, moving to a new house, newborns, children going to school and so on in the past year?," "How many meals did your guests have at your home in the last week, calculated by person?" and "Have you engaged in the following social activities in the past month?." Using the principal component analysis method (30), standardized data transformation through the idea of dimensionality reduction transformed multiple indicators into a relatively comprehensive friendship measurement index (30), which focuses on reflecting the degree of closeness between an individual and the friendship network, and is defined as hosnet_F. Firstly, KMO analysis was performed on the three selected groups of variables and the results showed that principal component analysis could be performed (see Table 1). According to the results of the principal component analysis in Table 2, the horizontal line at the point where the eigenvalue is equal to 1 of the gravel diagram (see Figure 1) is the cut-off point of the retained principal component, and the first principal component is selected to measure the friendship (Figure 3; Table 3).

3.2.3. Control variables

In this study, a total of 10 control variables were set from the three levels of individual, family, and region, which are, respectively: (1) Personal characteristic variables, including age, gender, education level, marital status, health status, and social security; (2) family characteristic variables, which mainly refer to monthly household expenditure, household size, etc.; (3) regional characteristic variables, including urban dummy variables and provincial dummy variables. The geographical location and

TABLE 2 Results of principal component analysis of the friendship index.

Principal component	Eigenvalue	Proportion	Cumulative contribution rate
Comp1	1.06202	0.3540	0.3540
Comp2	0.96993	0.3233	0.6773
Comp3	0.96805	0.3227	1.0000

FIGURE 3
Rubble diagram of PCA.
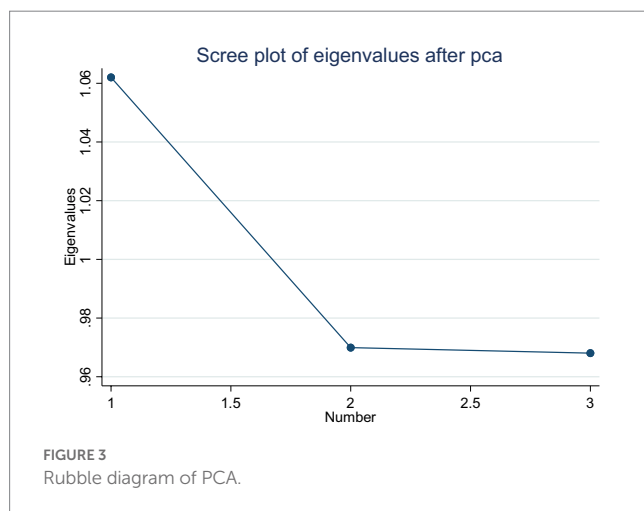
TABLE 3 Descriptive statistics of friendship indicators (principal component analysis).

Variables	Sample size	Mean	Max	Min	Standard deviation
hosnet_F	11,502	8.37e-09	36.8922	−0.6346	1.0305

economic gap of different regions will affect residents' choice of long-term care model.

The specific description of each variable in the model and some descriptive statistics are shown in Table 4.

3.3. Model setting and strategy

Logistic regression is the most widely used basic method in the field of statistical analysis, which is often used to simulate the probability of things happening. As the explained variable in this paper is $care\_all$, which is a virtual binary variable, and compared with the Probit model, the regression coefficient of the logistic model is easier to explain its economic significance, so this study adopts the binary logistic model for analysis:

$$\log it(P) = \ln \frac{P}{1-P} = \alpha + \sum_{i=1}^{n} \beta_i X_i \tag{1}$$

Based on the logistic regression model described above, two models were constructed with the same characteristics, including

individual characteristics, family characteristics, and regional characteristics. The difference was that the explanatory variable of Model 1 was modeled using $hosnet\_R$ in strong social relations. Model 2 was modeled using the friendship $hosnet\_F$ in strong social relationships. The specific model is as follows:

Model 1:

$$P(care\_all = 1 | hosnet\_R, X) = \varphi(\alpha + \beta_1 hosnet\_R + \beta_2 X + \varepsilon) \tag{2}$$

Model 2:

$$P(care\_all = 1 | hosnet\_F, X) = \varphi(\alpha + \beta_1 hosnet\_F + \beta_2 X + \varepsilon) \tag{3}$$

where $care\_all = 1$ represents the probability of respondents choosing the formal care model, and $care\_all = 0$ represents the probability of respondents choosing informal care; $hosnet\_R$ and $hosnet\_F$ are the core explanatory variables of this study, kinship and friendship; X is the relevant control variables that influence the respondents' choice of long-term care model, including personal characteristics, family characteristics, and regional characteristics; and ε represents the random error term.

4. Research results and analysis

4.1. Sample characteristics and correlation analysis

By showing the answers to the questions in the CHARLS 2018 questionnaire, this study presents some descriptive statistics of the respondents' personal characteristics, family characteristics, and regional characteristics. As shown in Table 5, the proportion of surveyed groups choosing a formal care model accounted for only 19.75%, indicating that the formal care model in China still has space to develop. Comparing the group that chose the formal care model with the group that did not, the average age of the group that chose the formal care model was 1.69 years older than the group that did not choose the formal care model, indicating that the older the group, the greater the demand for formal care, and also indicating that there may be a certain adverse selection tendency for the formal care model. At the same time, comparing the social security level of the group that chose the formal care model and the group that did not shows that the group with social security was more inclined to choose the formal care model.

From the perspective of the regional characteristics of the respondents, compared with the residents in rural areas, the proportion of urban residents choosing the formal care model was higher than that of the former. The proportion of residents in east China choosing the formal care model was higher than that in mid-west China, which indicates to some extent that the choice of long-term care model may be affected by the local formal care physical facilities and economic development level. At the same time, regional differences may lead to differences in the concept of old-age care and also have an impact on the choice of formal care model by middle-aged and older adults.

TABLE 4 Descriptive statistics of main variables.

Metrics	Variables		Meaning	Mean	Description of value
Dependent variable	care_all		Use of home and community older adult care services	0.1975	1 = Chose formal care, 0 = Chose informal care
Independent variables	hosnet_R		Kinship	1.4961	Maximum = 14.0037, Minimum = 0, Standard deviation =1.4961
	hosnet_F		Friendship	8.37e-09	Maximum = 36.8922, Minimum = −0.6346, Standard deviation =1.0305
Control variables	Personal characteristics	Age	Age	64.8572	Maximum =121, Minimum =45, Standard deviation =10.2065
		Gender	Gender	0.4730	0 = Female, 1 = Male
		Edu	Education background	0.1269	0 = High school diploma or below, 1 = High school diploma or above
		Married	Marital status	0.8508	0 = Others, 1 = Married
		Health	State of health	0.2501	0 = Fair or bad, 1 = Good
		Insurance	Social Security	0.9697	0 = Uninsured, 1 = insured
	Family characteristics	L_expen	Household expenditure logarithm	7.1346	Maximum =11.9184, Minimum = −2.3026, Standard deviation =1.0272
		Family	Household size	7.1346	Maximum =20, Minimum =0, Standard deviation =1.8437
	Regional characteristics	Urban	Rural and urban dummy variable	0.2888	0 = Rural, 1 = Urban
		Province	Provincial dummy variable	0.3090	0 = Mid-west China, 1 = East China

TABLE 5 Individual characteristics and descriptive statistics of samples.

Chose formal care model	Sample proportion	Average age	Household size	Proportion with high school education or above
Yes	19.75%	73.57	3.05	8.82%
No	80.25%	71.88	3.08	9.58%
Chose formal care model	**Proportion of urban areas**	**Proportion of east China**	**Proportion of social security**	**Proportion of healthy population**
Yes	27.06%	37.07%	98.02%	21.95%
No	26.69%	30.07%	96.71%	20.79%

4.2. Analysis of regression results

The baseline regression results of kinship and friendship are shown in Table 6. In the strong social relationship, column (1) only carries out regression for the core explanatory variable $hosnet\_R$, while all variables are controlled in column (2). The estimated odds ratio between the two is small and in the same direction, which can eliminate the problem of missing variables to a certain extent. According to the results of column (1) and column (2) of kinship relations, $hosnet\_R$ has a positive promoting effect on the selection of the formal care model for middle-aged and older adults, which verifies hypothesis H1.2 and excludes hypothesis H1.1. This shows that the increasingly compact and dispersed family structure in China

can no longer meet the increasing long-term care demands of middle-aged and older adults. Residents have to choose other ways to disperse the pressure of family care, which sparks the demand for the formal care model, demonstrating that family relationships have a "squeezing effect" on formal care for middle-aged and older adults. The above results indicate that residents are gradually realizing that the combination of the traditional "child-rearing" family care model and the socialized formal care model can better meet the long-term care needs of middle-aged and older adults.

The results of column (1) and column (2) of friendship indicate that $hosnet\_F$ has a positive impact on the choice of the formal care model among Chinese middle-aged and older adults, which supports hypothesis H2.1 but excludes hypothesis H2.2. The baseline regression

TABLE 6 Results of baseline regression.

Variables		Kinship		Friendship	
		(1)	(2)	(1)	(2)
Personal characteristics	hosnet_R	1.063*** (2.80)	1.091*** (3.55)	-	-
	hosnet_F	-	-	1.147*** (4.16)	1.128*** (3.43)
	Age		1.03⁶*** (7.28)		1.036*** (7.52)
	Gender		1.048		1.045
	Edu		0.914		0.900
	Married		0.881* (−1.61)		0.934
	Health		1.069		1.065
	Insurance		1.736** (2.47)		1.684** (2.51)
Family characteristics	L_expen		1.032		1.038
	Family		1.010		1.000
Regional characteristics	Urban		1.007		1.070
	Province		1.318*** (3.94)		1.403*** (5.01)
Sample size		6,273	5,658	6,778	6,054
Adjusted R-squared		0.0012	0.0168	0.0024	0.0177

Z-values in parentheses. ***, **, and * are significant at the level of 1%, 5%, and 10%, respectively.

TABLE 7 Robustness test of strong social relationship influence.

Variables	Logit (1)	Logit (2)	Probit (1)	Probit (2)
Clan	1.114** (1.93)	-	-	-
Friend	-	1.111*** (4.38)	-	-
hosnet_R	-	-	0.0503*** (3.56)	-
hosnet_F	-	-	-	0.0720*** (3.42)
Other variables (same as Table 6)	Yes	Yes	Yes	Yes
Sample size	9,630	9,630	5,638	6,054
Adjusted R-squared	0.0172	0.0188	0.0171	0.0188

Z-values in parentheses. ***, **, and * are significant at the level of 1%, 5%, and 10%, respectively.

results show that the transmission and perception of risk by residents communicating with friends will increase the possibility of middle-aged and older adults choosing the formal care model. At the same time, residents may transmit the behavior of choosing the formal care model among groups by imitating the behavior of friends, which is conducive to the improvement of the selection rate of the formal care model.

Meanwhile, the baseline regression empirical results show that "age" has a significant positive impact on the choice of the formal care model for middle-aged and older adults, indicating that, with the increase of age, the risk of disability and dementia of residents gradually increases, which leads to a gradual increase in the demand for the formal care model. According to the empirical results, "social security" also has a significant positive impact on the explained variable (care _ all), and the groups with social security are more inclined to choose the formal care model. In terms of regional characteristics, samples from east China have a significant positive impact on care _ all. The economic development level of east China is higher than that of mid-west China, and the physical facilities and institutions related to formal care are better and more popular, which

is conducive to middle-aged and older adults choosing the formal care model.

4.3. Robustness test

As for the robustness of the above results, this study adopted two methods to test them. The robustness test results are shown in Table 7: first, regression is conducted by replacing the core explanatory variables and the descriptive statistics of the replacement variables are shown in Table 8. In terms of kinship, this study drew on the practice of Wang Peihui (30) and selected 10 sets of data from CHARLS 2018, including "How much financial support did you or your spouse give/receive to other relatives and friends who are not parents, children or siblings that you do not live with in the past year?" and "How much money have you or your spouse given/received in the past year to other relatives or friends you do not live with who are not parents, children, or siblings?" and standardized the variables after the sum to build the kinship indicator clan in the robustness test. The method of normalization is to assign the value of 1 to the sum of economic

TABLE 8 Statistical characteristics of the replacement explanatory variables in the robustness test of strong social relations.

Variables			Sample size	Mean	Standard deviation	Min	Max
Independent variables	Kinship	Clan	19,828	0.5460	0.4979	0	1
	Friendship	Friend	19,828	0.7048	1.1199	0	6

TABLE 9 Results of heterogeneity analysis.

Variables	Provinces		Urban and rural	
	East China	Mid-west China	Urban	Rural
hosnet_R	1.043 (0.99)	1.121*** (3.75)	1.064 (1.30)	1.102*** (3.37)
hosnet_F	1.094 (1.31)	1.143*** (3.24)	1.126* (1.75)	1.131*** (2.97)
Other variables	Yes	Yes	Yes	Yes
Sample size	1744	3,914	1,506	4,152
Adjusted R-squared	0.0102	0.0204	0.0147	0.0201

Z-values in parentheses. ***, **, and * are significant at the level of 1%, 5%, and 10%, respectively.

transactions and the rest to 0. For the relationship between friends, this study selected the question "How often have you made the above social contact in the past month?" from CHARLS 2018 data. The friend relation index in the robustness test is defined as the frequency of communication between an individual and his friends. By repeating the previous regression steps with the substitution variables, while keeping the other conditions unchanged, the results obtained were consistent with the original results.

Secondly, this paper uses the probit model to re-estimate the impact of strong social ties on the long-term care patterns of middle-aged and older adults. Under the condition that the control core explanatory variables and other variables remain unchanged, the results obtained by changing the regression model were basically consistent with the benchmark regression, and the core explanatory variable coefficients of kinship and friendship in the probit model were all significant at the 1% level.

4.4. Heterogeneity analysis: regional and group differences

Due to the vast size of China, the economic development levels and cultural customs of different areas where residents are relatively different leads to certain differences in the strong social relations, which affects middle-aged and older adults' choice of long-term care model. Therefore, this study analyzed the heterogeneity of provinces and urban and rural areas, and the regression results are shown in Table 9.

From the perspective of regional characteristics, the positive effect of *hosnet_R* on the selection of the formal care model *care_all* was more significant in the mid-west and rural areas, but had no significant effect on east China and urban areas. The concept of clan and kinship was stronger in rural areas and mid-west China. Kinship had a greater impact on local residents' choice of daily behavior and thus on their choice of long-term care model.

For *hosnet_F*, the choice of *care_all* was significantly affected by friendship in mid-west China, while not significantly affected by the relationship of friends in east China. This indicates that the social network dominated by strong social ties still plays an important role

in the life of residents in mid-west China. From the perspective of urban and rural areas, friendship had a positive and significant impact on both urban and rural residents.

4.5. Analysis of influence mechanism: "SIRS Infectious Disease Model"

Referring to the existing literature, this paper adopted the "SIRS infectious disease model" to explore the influence of strong social relations on the choice of long-term care model for middle-aged and older adults (31). The SIRS infectious disease model mainly describes the abstract process of information transmission. S, I, and R stand for susceptible, infective, and removed, respectively. In this paper, under the effect of strong social relations, assuming that the economy is a closed economy and the total number of people at time t is N(t), the overall selection of the market for long-term care models can be regarded as people who did not choose formal care model S(t), people who perceived risk but did not choose formal care model I(t), and people who chose formal care model R(t). α represents the strength of strong social ties and β represents the learning and imitation behaviors caused by strong social relationships. The group S(t) who did not choose the formal care model and the risk-sensing group I(t) transmitted information through social interactions to stimulate their own risk perception. Part of the risk-sensing group βI chose formal care behaviors through imitation and learning behaviors. δI indicates that although the risk-sensing population I(t) senses the risk, it still does not choose the formal care model. Under the action of time t, it returns to S(t). λR refers to the group of people who chose the formal care model before and then did not choose to return to S(t), and the dynamic change of the formal care market is shown in Figure 2. At the same time, it is assumed that: (1) the population remains a constant, i.e., $N(t) \equiv N$ (2) each population contact must have a certain infectivity, that is, α, β, λ, and δ are greater than 0; (3) in the initial state, $S \gg I > R$. According to the dynamic transformation of the formal care market, the dynamic equation is constructed (Figure 4).

FIGURE 4
Dynamic model of the formal care market and strong social relationships.
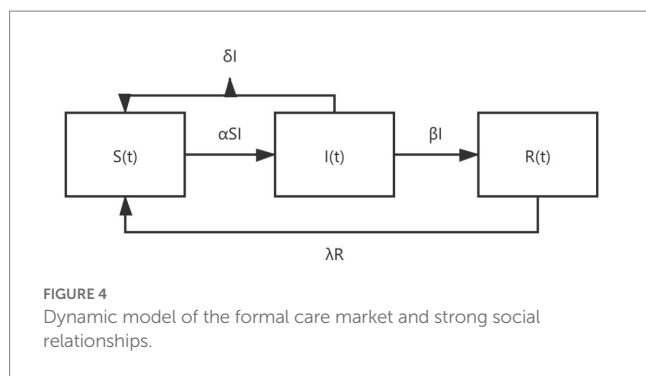
TABLE 10 Analysis results of influence mechanism.

Variables	Medical (1)	care_all (2)	care_all (3)
Medical	–	1.823*** (4.58)	1.402* (1.76)
hosnet_R	1.004 (0.13)	1.097*** (3.65)	1.099** (1.76)
Other variables	Yes	Yes	Yes
Sample size	9,181	5,403	1,124
Adjusted R-squared	0.0403	0.0208	0.0281
Variables	medical (1)	care_all (2)	care_all (3)
Medical	–	1.787*** (4.56)	1.444* (1.95)
hosnet_F	1.082** (2.50)	1.123*** (3.20)	1.220** (2.33)
Other variables	Yes	Yes	Yes
Sample size	9,832	5,766	1,200
Adjusted R-squared	0.0408	0.0209	0.0351

Z-values in parentheses. ***, **, and * are significant at the level of 1%, 5%, and 10%, respectively.

$$\frac{dS(t)}{dt} = -\alpha S(t)I(t) + \lambda R(t) + \delta I(t) \tag{4}$$

$$\frac{dI(t)}{dt} = \alpha S(t)I(t) - \beta I(t) - \delta I(t) \tag{5}$$

$$\frac{dR(t)}{dt} = \beta I(t) - \lambda R(t) \tag{6}$$

Since the total population N of this economy is assumed to be constant in this study, the equation R = N-S-I can be obtained as follows:

$$\frac{dS(t)}{dt} = -\alpha S(t)I(t) + \lambda\big[N - S(t) - I(t)\big] + \delta I(t) \tag{7}$$

$$\frac{dI(t)}{dt} = \big[\alpha S(t) - \beta - \delta\big]I(t) \tag{8}$$

Set the above two equations equal to 0 and the above steady-state value can be obtained as:

$$S^* = \frac{\beta + \delta}{\alpha} \tag{9}$$

$$I^* = \frac{\alpha\lambda N - (\beta + \delta)\lambda}{\alpha(\beta + \lambda)} = \frac{\lambda N}{\beta + \lambda} - \frac{(\beta + \delta)\lambda}{\alpha(\beta + \lambda)} \tag{10}$$

$$R^* = \frac{\beta(N\alpha - \beta - \delta)}{\alpha(\lambda + \beta)} \tag{11}$$

It can be seen from the steady-state value that, at S^*, each group reaches an equilibrium state in the formal care market. Among them, the group S^* that does not choose formal care will decrease with the increase of interaction frequency α between groups, which means that more people switch to risk perception group I^* and choose formal care group R^* indicating that strong social relationships will affect the group's demand for the formal care model.

In this paper, the "SIRS infectious disease model" is constructed to clarify the influence mechanism between strong social ties and the formal care model. In the empirical regression, questions such as "Do you participate in supplementary medical insurance?" in the 2018 CHARLS questionnaire were selected to construct the medical transfer payment index medical. The analysis results are shown in Table 10. The regression results of model (1) and model (2) show that the group that attaches more importance to strong social ties will increase medical transfer payments, thus increasing the demand for the formal care model. In model (3), sample individuals were limited to healthy individuals (heath = 1), and the results were still significant, indicating that even though individual residents themselves did not suffer from disability risk, risk information transmitted by strong social relationships would stimulate their own needs for the formal care model.

5. Conclusion and discussion

Faced with the increasingly severe problem of population aging in China and the phenomenon of smaller family sizes and fewer children, the development of the formal care model plays an important role in alleviating the pressure of care for middle-aged and older adults. The research results show that strong social relations, as an important "reference point" in residents' daily life, play an important role in residents' behaviors and choices, and the relationships with relatives and friends will affect the behavioral decisions of middle-aged and older adults in China, which is consistent with previous research results (16, 32), and will have a certain impact on their choice of care model. Strong social relationships such as kinship and friendship tend to contribute to the choice of formal care models among Chinese middle-aged and older adults through transmission mechanisms such as risk perceptions (3). At the same time, Due to the large regional differences and the special urban-rural dual structure in China, there are also obvious regional and urban-rural differences in the results: mid-west China and rural areas are more significantly influenced by

strong social ties, while east China and urban areas do not show significant results.

Based on the above results, this study puts forward the following recommendations for the development of the formal care model: firstly, it should be clear that there is a certain competition and cooperation relationship between strong social relations and the formal care model in terms of risk dispersion and transfer. Influenced by the traditional concepts of "raising children for old age" and "mutual assistance from relatives," the family care and old-age care model is still the first choice for Chinese residents. China should explore more innovative formal care models such as home care and community joint care, and focus on the development of neighborhood (township) and urban and rural community pension service networks, so as to realize the gradual transition from family care to formal care. Secondly, the establishment of good and strong social network relations should be promoted, using strong social relations to promote formal care model. The study and imitation effect of relative relations and friends produce important influence on the choice of daily behavior of Chinese residents, so China should encourage good social relations, and encourage relatives and friends to help each other. Through propagating and popularizing formal care knowledge among strong social networks, the information and education of older adult health knowledge in urban and rural communities is strengthened, the health literacy of older adults is improved, and the formal care model is promoted. Furthermore, through the establishment of a harmonious and friendly strong social network, the old-age care system to provide informal protection for relieving the care pressure of middle-aged and older adults is enriched.

The innovation of this study lies in the fact that, starting from the "differential pattern" of traditional Chinese relationships, kinship based on blood relationships and friendship based on business relationships and interest relationships were selected as "strong social relationships." This paper explains the influence of different strong social relations on residents' choice of care mode, and tries to give an explanation. It is a supplement to the previous research and provides a reference for the existing research on how other social relations affect the choice of residents' care model. At the same time, this study still has some shortcomings. Due to data limitations, most databases are only updated to 2018, and some variables are not continuous, so they cannot be sorted into microscopic panel data, which is also the limitation faced by most empirical papers at present. Furthermore, there are many kinds of interpersonal relationships, so it is difficult to cover them all. This study can only focus on the relative major strong social relationships, and the demonstration of secondary relationships needs to be further explored.

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

Zhao X. contributed to the conception and design of the study, organized the database, performed the statistical analysis, and wrote the first draft of the manuscript. Xing H. and Jing T. validated the statistical analysis and reviewed, edited, and revised sections of the manuscript. Bao C. and Zhan L. contributed to manuscript methodology and software, revision, and read and approved the submitted version of the manuscript.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1112422/full#supplementary-material

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Quality of life profiles and their associations with depressive symptoms and cognitive impairment of community-dwelling older adults in Hong Kong

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Background: This study aimed to (1) explore the quality of life (QoL) profiles of older adults in Hong Kong and (2) examine their association with predictors (age, sex, body mass index, and depressive symptoms) and distal outcome (cognitive impairment) using a person-centered approach.

Methods: A total number of 328 community-dwelling older adults in Hong Kong were invited to participate in this study. Data from 259 older adults were identified as valid for the primary analysis. Latent profile analysis was used to explore QoL profiles. Multinomial logistic regression using the R3STEP function in Mplus was used to explore the predictive role of age, sex, body mass index, and depressive symptoms in profile membership. The Bolck-Croon-Hagenaars approach was used to examine how the distal outcome of cognitive impairment differs as a function of QoL profiles.

Results: Three QoL profiles emerged from the latent profile analysis (Low, Moderate and High QoL). It was found that depression, but not age, sex, or body mass index, significantly predicted QoL profile membership. The results of the Bolck-Croon-Hagenaars analysis revealed no significant differences in cognitive impairment across the three QoL profiles.

Conclusion: This is the first study that examined the relationship between QoL, depressive symptoms and cognitive impairment of older adults using a person-centered approach. The findings provide additional information for the evidence obtained from variable-centered approach on the associations among variables abovementioned. Our additional focus on the antecedents of emergent QoL profiles also provide practical knowledge regarding timely treatment for or prevention of depressive symptoms, which we submit will be crucial for enhancing the QoL of older adults.

KEYWORDS

quality of life, depression, cognitive impairment, older adults, latent profile analysis

1. Introduction

Life expectancy in Hong Kong (HK) has steadily increased over the past few decades. According to the Hong Kong Census and Statistics Department (1), the older adult population, those individuals who are at least 65 years of age, will reach 2.58 million (35%) by 2069, compared to 1.32 million (17.5%) in 2019. Aging is usually accompanied by a decline in physical and cognitive functioning (2) and therefore, the dramatic increase in life expectancy and, consequently, the size of the aging population is likely to create economic and social challenges for the government. In the 2015 financial year, the HK government spent HK$55.3 billion on the older adults, and this figure is expected to increase to HK$142.9 billion by 2064. In addition, a high suicide rate has been observed in older adults in HK, with an average rate of 26.8% for the period 1981 to 2015. In 2014, older adults comprised 15% of the HK population but accounted for 29.3% of all deaths due to suicide. This is a much larger proportion than that of other age groups (3). Both the physical and mental components of quality of life (QoL) have been identified as main factors that precipitate suicide in older adults (3). Previous research has also revealed that QoL can be used to predict cardiovascular disease, future hospitalization, and all-cause mortality (4–6). In light of these alarming statistics and significant consequences, it is submitted that the HK government should pay attention to the QoL of the older adult population, as it is not only important for the wellbeing of older adults in general, but also the happiness of thousands of families and the development of society (7).

Researchers have extensively explored and examined the concept and constructs of QoL. It is widely accepted that QoL is a multidimensional concept, although consensus on the specific components of QoL has not yet been achieved (7–11). According to the World Health Organization (WHO) definition, QoL refers to "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns" (12). This definition emphasizes that QoL is a subjective view of one's life and is influenced by various factors (13, 14). Previous research has thoroughly investigated the factors that may affect QoL in older adults. Depressive symptoms have consistently been found to be negatively associated with QoL in older adults (15–19). A meta-analysis review summarizing the results of 84 studies revealed that older adults with depression had poorer QoL than older adults without depression, and that an increase in depression severity was associated with a poorer QoL (9). More importantly, these associations were found to be stable over time and independent of how QoL was assessed. However, previous findings on the relationships between QoL and age, body mass index (BMI), and sex among older adults were mixed. For example, previous research in the United Kingdom (UK) has suggested that the QoL of older adults decreased significantly over 4 years, with a more rapid decline rate in later life (20). In contrast, results from studies conducted on older persons with mild cognitive impairment in China revealed very little change in QoL over 4 years (21), which suggests that a decline in QoL with age is not inevitable. Similar results were also reported in another longitudinal study, in which no substantial relationship between age and average change in QoL scores among adults aged ≥70 years was observed (22). This is consistent with Netuveli and Blane's argument that an extended period of good QoL is possible

since aging does not automatically negatively influence QoL (23). Inconsistent findings on the correlation between BMI and QoL among older adults have also been reported in previous studies. For example, some scholars found that BMI was not associated with QoL in older adults, especially in the Asian population (24, 25). However, other studies have reported that BMI was negatively associated with QoL in older adults (26–30). It is noteworthy that BMI was treated as both a continuous and categorical variable in previous research, which may have influenced the conclusions in these studies. Moreover, the relationship between BMI and QoL was found to be moderated by sex (28, 30), which suggests that the correlation between sex and QoL necessitates further investigation. Previous research has revealed inconsistent conclusions regarding the correlation between sex and QoL. For example, the results of a study with a large sample ($n = 33,109$), including older adults from China, Ghana, India, Russia, and South Africa, suggested that male older adults reported a better QoL than their female counterparts across all of the countries (31). A recent study conducted among Taiwanese Chinese older adults found that women experienced significantly higher QoL than men (32). However, previous findings concerning older adults in Brazil suggested that sex was significantly associated with QoL, but this relationship was moderated by other factors such as retirement status and physical or mental health status (33). Moreover, the results of a study on older adults in Iran suggested that sex was not associated with QoL of these older adults (34). Collectively, these inconsistent results indicate that further research needs to be conducted to explore the correlations of QoL with age, sex, and BMI.

Although some studies have revealed that QoL is associated with cognitive impairment in older adults, this relationship is complex (35, 36). Certain previous studies have shown that cognitive training intervention is protective against health-related QoL decline (37), which suggests that cognitive impairment may be a predictor of QoL. However, it has also been reported that poor QoL may result in low engagement in physical and social activities, which are risk factors for cognitive decline (38). Following the same logic, recent research has consistently demonstrated the predictive role of QoL in cognitive impairment and dementia onset in older adults (35, 39). A recent longitudinal study on middle-aged and older Chinese patients with diabetes, showed that participants' health-related QoL (HRQoL) at Time 1 significantly predicted their cognitive impairment at Time 2 (40). Although previous mixed findings imply a bidirectional relationship between QoL and cognitive impairment, there is more evidence to support a predictive role of QoL on cognitive impairment.

Collectively, previous studies on the correlation of QoL with some of its predictors and consequences were mixed and we submit that as a result of this topic deserves further attention. However, it is worth noting that previous research has relied mainly on the variable-centered approach, which explores the associations among variables and provides an overall picture of the average relationships across the population (41). Variable-centered approaches are limited in that they overlook population diversity and intra-individual variability. In contrast, a person-centered approach identifies groups of individuals who share similar attributes or relations among attributes and thus allows researchers to examine how perceptions of QoL domains can be combined within individuals and relate to other variables (42). Latent profile analysis (LPA), as a

person-centered approach, is based on a model and adopts strict statistical criteria to properly control class variables (43). As a result, it has been widely used in various settings. Although some studies explored the QoL profiles of specific (people with stoma, Islamic Inabah substance abusers, youth and young adults with sickle cell disease, homeless persons, long-term cancer survivors) (44–48), and general (Vietnamese people) (49) populations, research that has employed LPA to explore the QoL profiles of older adults and their relationships with antecedent or consequent variables is scarce. A recent study among Korean older adults explored HRQoL profiles and their relationships with selected predictors using a person-centered approach (latent cluster analysis [LCA]) (50). Four latent classes (stable type, physical disability type, emotional disability type and crisis type) emerged based on the HRQoL status measured using EQ-5D, which measures five aspects of HRQoL: mobility, self-care, usual activity, pain/discomfort, and anxiety/depression (51). Factors such as low income, household type, hypertension, number of falls, depression, and discomfort resulting from cognitive decline, happiness, frequency of contact, trust in the social environment, and participation in social activities significantly predicted latent classes. However, age and sex, which were considered potential predictors, were controlled. Moreover, only predictors, but not outcomes, of the HRQoL profiles were examined in this study.

To further advance our understanding of the QoL of older adults and its associations with antecedent and outcome variables, the current study aims to (1) explore the QoL profiles of a sample of community-dwelling older adults in HK using LPA; (2) examine the predictive role of age, sex, BMI, and depressive symptoms on the QoL profile membership; and (3) investigate profile differences in the distal outcome of cognitive impairment. Given the limited studies that have been conducted on these questions, no specific profile combinations were hypothesized. In relation to antecedent variables, no specific assumptions were made regarding age, sex, and BMI since mixed findings were reported in previous research. However, we hypothesized that older adults' depressive symptoms would significantly predict QoL profile membership. It was also anticipated that the outcome variable of cognitive impairment would differ significantly across the QoL profiles.

2. Methods

2.1. Participants and procedure

A total number of 328 community-dwelling older adults from seven community centers for older adults in different districts of HK (Kowloon = 2, New Territories = 3, Hong Kong Island = 2) were invited to participate in this study. District community centers are a type of community support service at the district level that enable older adults to remain in the community while leading a healthy and dignified life. All people who are 60 years old qualify to register as members of community centers, join activities organized by the centers and seek assistance and support from the centers. This research was reviewed and approved by the Human and Animal Research Ethics Committee of a local university. The data were collected between March 2017 and April 2018 by eight research assistants who participated in a 3-h training workshop before data collection began. This training was carried out to homogenize and standardize the assessment methods in order to reduce inconsistencies among the data collected. Data collection was conducted at the district community centers using a one-on-one face-to-face interview format. The research assistants asked the participants questions according to the sequence prescribed by each assessment tool and recorded the responses. Written informed consent was obtained from each participant prior to data collection. After excluding incomplete and invalid responses, data from 259 older adults were identified as valid for the main analysis.

2.2. Measures

2.2.1. Quality of life

The Chinese version of the World Health Organization Quality of Life-OLD (WHOQOL-OLD) (11) was used to measure the participant's QoL. The initial WHOQOL-OLD module includes six facets (sensory abilities; autonomy; past, present, and future activities; social participation; death and dying; and intimacy) with four items for each facet. The responses were provided on a 5-point Likert scale ranging from 1 = "not at all" to 5 = "an extreme amount." Three items from the sensory abilities facet (OLD_01, OLD_02, and OLD_10) and four items from the death and dying facet (OLD_06, OLD_07, OLD_08, and OLD_09) were reverse coded. Higher scores indicate a higher QOL. Facets and scale scores were transformed to a scale of 0–100. Previous research has demonstrated that the Chinese version of the WHOQOL-OLD has satisfactory validity and reliability (52). The WHOQOL-OLD demonstrated acceptable factorial validity, $\chi^2 = 320.89$, df = 237, CFI = 0.936, TLI = 0.926, RSEMA = 0.037 (90% CI: 0.026–0.047), SRMR = 0.065, and satisfactory internal consistency reliability (with composite reliability ranging from 0.65 to 0.857) in this study.

2.2.2. Depressive symptoms

The Chinese version of the Geriatric Depression Scale-Short Form (GDS-SF) (53) was used to evaluate the participant's depressive symptoms. The assessment tool includes 15 items with each item being rated on a dichotomous scale of "yes" or "no" yielding a score range of between 0 and 15. A higher score indicates a higher level of depressive symptoms. Participants with a score equal to or greater than eight were considered likely to be depressed. Previous research has consistently demonstrated that the Chinese version of the GDS-SF has satisfactory validity and reliability (53–55).

2.2.3. Cognitive impairment

The Cantonese version of the Mini-Mental State Examination (MMSE) (56) was used to assess the cognitive impairment of participants. The Cantonese version of the MMSE (C-MMSE) is an 11-item instrument. Most items of the MMSE were directly translated and used in the C-MMSE during this study, but major adaptations had to be made for several items. For example, the phrase "no if's, and's or but's" was replaced with the phrase "姨丈買魚腸" which is translated to "Uncle buys fish intestine," an alliteration in Cantonese. The maximum score for the C-MMSE is 30, and a cut-off value of 19/20 is recommended as an indication that cognitive impairment may require further evaluation. Previous research has demonstrated that the C-MMSE displays satisfactory validity and reliability among Chinese older adults in Hong Kong (56).

2.3. Plan of analyses

Descriptive statistics and correlations of all main variables were calculated using the IBM Statistical Package for Social Science (SPSS) (Version 22 IBM, Armonk, NY). LPA using the six QoL domains of the WHOQOL-OLD as profile variables was conducted using Mplus (Version 7.31) with Robust maximum likelihood (MLR) to explore solutions from one to four profiles. A combination of relative fit indices, including the log likelihood value (LL), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Adjusted Bayesian Information Criterion (ABIC), entropy, Lo–Mendell–Rubin adjusted Likelihood Ratio test (aLRM), and bootstrapped likelihood-ratio test (BLRT), were employed to choose the best solution. Smaller values of the AIC, BIC, and ABIC and higher values of the LL and entropy are indicative of a better solution. The aLMR compares the estimated model (k) with a model that has one class less than the estimated model (k-1). Non-significant p values support the k-1 profile model. Higher entropy suggests a more accurate classification, ranging from 0 to 1. A multivariate analysis of variance (MANOVA) was conducted with the QoL profiles as the independent variable and six QoL domains as the dependent variables to examine the criterion validity of the LPA. Multinomial logistic regression using the R3STEP function (57) in Mplus was conducted to examine whether profile membership could be predicted by antecedent variables including age, sex, BMI, and depressive symptoms. Age and BMI were treated as continuous variables, and sex and depressive symptoms were dummy-coded (woman = 0, man = 1; GDS score lower than 8 = 0, GDS score equal to or above 8 = 1). The Bolck-Croon-Hagenaars approach (BCH) (58) approach in Mplus was employed to examine how the distal outcome of cognitive impairment differs across QoL profiles.

3. Results

3.1. Descriptive statistics and correlations

The descriptive statistics of the variables are presented in Table 1. Participants reported extremely low scores on the death and dying domains and moderate-to-high scores on the other five QoL domains. There were no significant sex differences in any of the variables except for height, body weight, and BMI. The bivariate correlations among the variables are presented in Table 2. Age and BMI were found to be significantly associated with certain QoL domains (autonomy and intimacy), cognitive impairment, and depressive symptoms. Furthermore, the autonomy domain was associated with depressive symptoms and cognitive impairment, while the death and dying domain was associated with depressive symptoms. In addition, low-to-moderate correlations were found among the QoL domains.

3.2. Latent profile analysis and profile description

Table 3 presents the statistical indicators and tests for the LPA models. We started with a solution with one profile as the minimum and then extended it progressively with more profiles

TABLE 1 Descriptive statistics of variables.

Variables	Total (n =259)	Male (n =57)	Female (n =202)	t
Age	78.46 (7.79)	78.37 (8.00)	78.48 (7.56)	−0.95
Height	151.96 (7.18)	159.05 (6.13)	149.95 (6.11)	9.926***
Weight	56.17 (9.05)	59.04 (9.71)	55.36 (8.71)	2.748**
BMI	24.34 (3.50)	23.40 (3.55)	24.60 (3.45)	−2.301*
SAB	55.12 (22.80)	59.98 (21.52)	53.74 (23.01)	1.832
AUT	70.10 (18.88)	70.50 (19.15)	69.99 (18.85)	0.182
DAD	20.51 (22.85)	15.39 (18.52)	21.95 (23.78)	−1.924
PPF	65.08 (20.91)	64.91 (22.15)	65.13 (20.61)	−0.069
SOP	76.13 (18.14)	73.14 (19.12)	76.98 (17.82)	−1.415
INT	62.11 (26.18)	61.80 (24.37)	61.35 (26.68)	0.878
GDS	7.15 (2.08)	7.10 (2.32)	7.17 (2.01)	−0.201
MMSE	23.01 (5.43)	23.91 (5.56)	22.75 (5.37)	1.427

***p < 0.001; **p < 0.01; *p < 0.05; BMI, body mass index; SAB, sensory ability; AUT, autonomy; DAD, death and dying; PPF, past, present and future activities; SOP, social participation; INT, intimacy; GDS, geriatric depression scale; MMSE, mini-mental state examination.

until the addition of one more profile did not significantly improve the model fit. The values of AIC, BIC, and SABIC decreased as the number of profiles increased. The aLMR in the four-profile model was nonsignificant, which indicated that a solution with three profiles was superior to the two-profile model. Moreover, it was found that the entropy value reached a peak in the model with three profiles. Therefore, a solution with three profiles was considered to be a satisfactory model. Figure 1 illustrates the three profiles. Profile 1 (n = 9; 3.5% of the sample) is characterized by low scores on five out of six QoL domains (with the exception of the sensory ability domain) and is labeled as a Low QoL profile. Profile 2 (n = 132; 50.9% of the sample) was characterized by moderate scores on five out of six QoL domains (with the exception of the death and dying domain) and labeled as a Moderate QoL profile. Profile 3 (n = 118; 45.6% of the sample) is characterized by high scores on four out of six QoL domains (with the exception of the sensory ability and death and dying domains) and is labeled as a High QoL profile.

The results of the MANOVA revealed a significant multivariate effect for profiles on QoL domains, Pillai's trace = 0.946, F (12, 504) = 32.675, p < 0.001, η^2 = 0.438. Follow-up univariate F-tests suggested significant effects of profiles on four out of six QoL domains (with the exception of the sensory ability and death and dying domains). All statistics are presented in Table 4. These results support the interpretability of LPA results.

3.3. Antecedent and consequent variables of QoL profiles

Table 5 presents the results of the multinomial logistic regression. It was found that depression, but not age, sex, or BMI, was significantly associated with profile membership, which suggests that the age, sex, and BMI of older adults may not contribute to their QoL status. However, older adults with

TABLE 2 Bivariate correlations among variables.

	Age	Height	Weight	BMI	SAB	AUT	DAD	PPF	SOP	INT	GDS
Height	−0.298**										
Weight	−0.174**	0.441**									
BMI	0.007	−0.162**	0.809**								
SAB	0.051	−0.006	−0.042	−0.036							
AUT	−0.142*	0.067	0.084	0.061	0.020						
DAD	−0.113	−0.015	−0.014	−0.008	−0.135*	−0.064					
PPF	−0.119	0.043	−0.041	−0.059	−0.004	0.391**	0.101				
SOP	−0.042	−0.059	−0.073	−0.029	0.073	0.374**	−0.040	0.594**			
INT	−0.147*	0.082	−0.078	−0.127*	0.103	0.325**	0.032	0.510**	0.469**		
GDS	−0.450**	0.274**	0.078	−0.100	−0.079	0.208**	0.096	0.016	0.019	0.092	
MMSE	−0.126*	−0.040	−0.044	−0.025	−0.122	−0.159*	0.161**	−0.054	−0.086	−0.081	−0.062

$**p < 0.01$; $*p < 0.05$; BMI, body mass index; SAB, sensory ability; AUT, autonomy; DAD, death and dying; PPF, past, present and future activities; SO, social participation; INT, intimacy; GDS, geriatric depression scale; MMSE, mini-mental state examination.

TABLE 3 Latent profile fit statistics for models based on the six quality of life domains.

Model	LL	Scaling	#FP	AIC	BIC	SABIC	Entropy	aLMR p-value	BLRT p-value	Smallest class %
1-Profile	−6966.989	1.071	12	13957.979	14000.661	13962.616	–	–-	–	
2-Profile	−6873.533	1.221	19	13785.066	13852.646	13792.409	0.710	0.0062	<0.001	42.857
3-Profile	−6817.770	1.023	26	13687.541	13780.018	13697.589	0.820	<0.001	<0.001	3.475
4-Profile	−6808.636	1.186	33	13683.271	13800.646	13696.025	0.723	0.7015	0.1463	3.475

LL, model log-likelihood; Scaling, scaling factor associated with MLR log-likelihood estimates; #FP, number of free parameters; AIC, Akaike information criteria; BIC, Bayesian information criteria; SABIC, sample-size adjusted BIC; aLMR, adjusted Lo–Mendell–Rubin likelihood ratio test; BLRT, bootstrap likelihood ratio.

depression were more likely to be members of the Low QoL profile relative to the Moderate QoL profile (OR = 5.512, $p < 0.01$) and High QoL profile (7.156, p < 0.01). In other words, older adults with depression were five and six times as likely to be allocated to the Low QoL profile relative to the Moderate and High QoL profiles as were their non-depressed counterparts, respectively. Table 6 presents the results of the difference tests on cognitive impairment across profiles using the BCH procedure. There were no significant differences found in cognitive impairment across the three QoL profiles ($\chi^2 = 3.955$, $p = 0.138$).

4. Discussion

Previous research on the QoL of older adults mainly employed variable-centered approaches to explore the average relationships of QoL with related antecedent and outcome variables. Adding to the body of knowledge in this subject area, the results of our study employed a person-centered approach to explore whether subgroups with distinct QoL profiles based on QoL domains can be identified among a sample of community-dwelling older adults in HK. Furthermore, we explored the associations of predictors (age, sex, BMI, and depression) with and differences in distal outcome (cognitive impairment) across QoL profiles. This study contributes to the literature in the field by increasing what is known about QoL profiles of older adults and examining the relationships between antecedents, QoL profiles, and the consequences from a person-centered perspective.

4.1. Quality of life profiles

To our knowledge, this is the first study to investigate this particular topic using latent profile analysis among older adults in HK. Three QoL profiles, namely Low QoL, Moderate QoL and High QoL, emerged from the analysis, and significant differences in most of the profile variables across the three QoL profiles were observed. Older adults with a Low QoL profile displayed a similar pattern, with low scores on five out of six QoL domains and an above-average score on the sensory ability domain. Accordingly, the sensory functioning of older adults in this group was good, but they experienced limited autonomy, were dissatisfied with their lives, appeared to be stuck in the past, did not participate frequently in social activities, lacked intimate relationships, and had negative feelings and thoughts about death or dying. This profile is similar to the "Low QoL" class some older adults in Sri Lanka fall into after utilization of K-mean cluster analysis, in which participants reported low scores on physical, mental, social, functional, environmental, and spiritual domains (59). It also shares similar characteristics with the profile of "crisis type" that emerged from Korean older adults using latent class analysis, in which older adults reported low scores on mobility, self-care, usual activities, pain/discomfort (50). Older adults with a High QoL profile reported a similar pattern of high scores on four out of six QoL domains, a moderate score on the sensory ability domain, and a low score, although slightly higher than their counterparts in the Low QoL profile in the death and dying domain. This means that although the participants might have had some sensory functioning concerns, they could make their own decisions, participate in regular social activities,
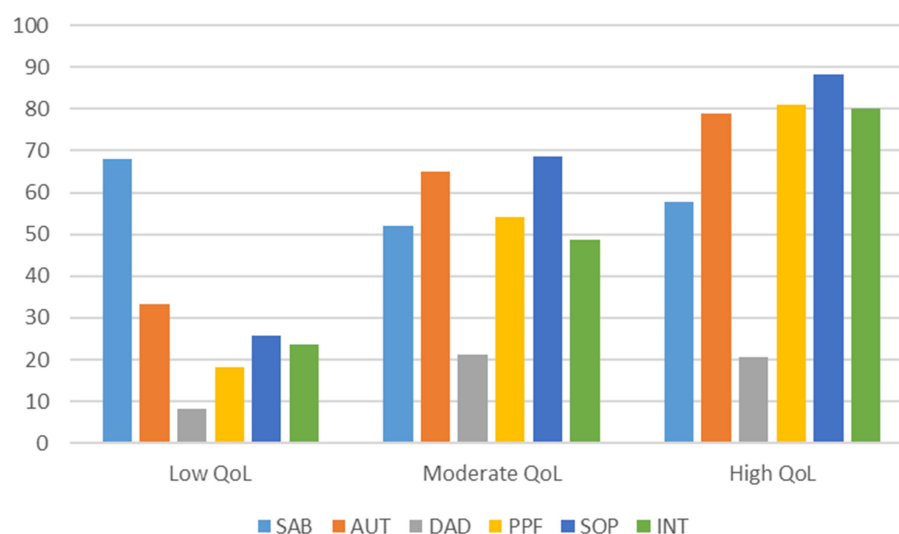
FIGURE 1
Three QoL profiles emerged from latent profile analysis. SAB, sensory ability; AUT, autonomy; DAD, death and dying; PPF, past, present and future activities; SOP, social participation; INT, intimacy.

TABLE 4 Group differences on profile variables.

	Profile 1 (n =9)		Profile 2 (n =132)		Profile 3 (n =118)		F	p	η^2	Profile difference
	M	SD	M	SD	M	SD	(2, 256)			
1. SAB	68.06$_a$	18.07	51.89$_a$	21.12	57.73$_a$	24.35	3.618	0.028	0.027	1 = 2 = 3
2. AUT	33.33$_a$	18.75	64.87$_b$	17.17	78.76$_c$	14.87	46.834	<0.001	0.268	3 > 2 > 1
3. DAD	8.25$_a$	10.55	21.32$_a$	23.83	20.54$_a$	22.36	1.383	0.253	0.011	1 = 2 = 3
4. PPF	18.06$_a$	10.10	54.12$_b$	14.17	80.93$_c$	13.17	176.524	<0.001	0.580	3 > 2 > 1
5. SOP	25.69$_a$	16.07	68.61$_b$	12.74	88.40$_c$	10.73	167.353	<0.001	0.567	3 > 2 > 1
6. INT	23.61$_a$	19.71	48.77$_b$	22.54	79.98$_c$	17.13	93.205	<0.001	0.421	3 > 2 > 1

Bonferroni correction was adopted for multiple group comparisons with p values were significant at 0.017. SAB, sensory ability; AUT, autonomy; DAD, death and dying; PPF, past, present and future activities; SOP, social participation; INT, intimacy. Values shared same subscript mean non-significant differences on values across groups.

have strong intimate relationships with others, and are satisfied with their lives in general. Surprisingly, they also reported low scores on the death and dying domain, similar to their counterparts in both Low QoL and Moderate QoL profiles. As illustrated in Table 1, the mean score of the sample in the death and dying domain was low. One possible reason may be that Chinese older adults in HK are sensitive to the topic of death and dying and overreacted to questions related to the topic. Unfortunately, there is no data available on Chinese older adults in HK on this subject from other studies. However, existing data on Chinese older adults in Mainland China using the same measure (WHOQOL-OLD) revealed a moderate to high score in this domain. Further research may need to be conducted on this issue in the future. The High QoL profile that emerged in this study shared similar characteristics with the "stable type" profile observed among Korean older adults (50) and "High QoL" profile of older adults in Sri Lanka (59), in which participants reported high scores on all QoL domains. However, given that different measures were used across the three studies, the profiles shared similar patterns of scoring in some related domains. Regarding the Moderate QoL profile, the participants in this profile reported a similar pattern of moderate scores on five out of six QoL domains but a low and similar score with their counterparts in

the High QoL profile in the death and dying domain. For this particular profile, it may be understandable, but no comparable profiles have emerged in respect of Korean older adults. The other two profiles that emerged from Korean older adults were the "physical disability type" and "emotional disability type." The former is characterized by extremely low scores on the mobility and pain/discomfort domains, whereas the latter is characterized by extremely low scores on the anxiety/depression domain (50). It is noteworthy that more than half of the participants (50.9%) were allocated to the Moderate QoL profile in the current study.

4.2. Antecedent and consequent variables of QoL profiles

Our results suggest that depression, but not age, sex, or BMI, significantly predicted QoL profile membership. The significant correlation between depression and QoL is consistent with previous research findings and provides further support for this relationship from a person-centered approach. In our analysis, depressive symptoms were dummy-coded (0 or 1) using a cut-off

TABLE 5 Results of multinomial logistic regressions for the effects of predictors on profile membership.

	Profile 1 vs. 3[a]		Profile 2 vs. 3[a]		Profile 1 vs. 2[a]	
	Coef. (SE)	OR	Coef.	OR	Coef.	OR
Age	0.016 (0.036)	1.016	0.035 (0.021)	1.035	−0.019 (0.036)	0.981
Gender	−0.982 (0.762)	0.374	0.160 (0.376)	1.173	−1.141 (0.771)	0.319
BMI	−0.016 (0.092)	0.984	0.059 (0.046)	1.061	−0.075 (0.092)	0.927
GDS	1.968** (0.895)	7.156	0.261 (0.322)	1.298	1.707** (0.899)	5.512

Dummy coding (GDS score lower than 8 = 0; GDS score equal to or above 8 = 1; Female = 0; Male = 1); Profile 1 = Low QoL; Profile 2 = Moderate QoL; Profile 3 = High QoL; SE, standard error of the coefficient (Coef); OR, odds ratio.
[a]Reference group.
*$p < 0.05$, **$p < 0.01$.

TABLE 6 BCH results for the differences on the cognitive impairment across latent profiles.

	Profile 1	Profile 2	Profile 3	Comparison
MMSE	22.30	22.509	23.609	1 = 2 = 3

MMSE, mini-mental state examination.

value of 8 for the GDS score, with a score lower than 8 coded as non-depression (0) and scores equal to or higher than 8 coded as depression (1). It was found that older adults with depression were more likely to be allocated to the Low QoL profile than to the Moderate or High QoL profiles. This result reasonably explains why older adults in the Low QoL profile had moderate scores in the sensory ability domain, but low scores in other domains. A moderate score on the sensory ability domain indicated that the sensory functioning of these older adults was above average and did not negatively influence their daily lives. Therefore, their low scores on autonomy, social activity participation, attitude toward the past, present, and future, death and dying, and intimacy with others may be the result of their depression since depressed individuals were more likely to isolate themselves from others, to be stuck in the past, and to be pessimistic about the present and future. Our results, together with previous findings, suggest that the prevention and treatment of depression is an important strategy to be pursued in improving and maintaining QoL in older adults (9, 19). An insignificant relationship between age and QoL was observed in this study, which is consistent with previous findings in Chinese older adults (21) as well as in other older adult populations (22). Practitioners, such as social workers, and family members of older adults are encouraged to abandon the stereotype that aging will inevitably result in poor QoL and rather utilize these findings to strengthen older adults' beliefs that they are in control of their QoL. The nonsignificant relationship found between BMI and QoL in this study is consistent with previous findings in the Asian population (24, 25). It should however be noted that BMI was treated as a continuous variable in our analysis, but that this is unlike in previous studies that treated BMI as a categorical variable (30). However, in Lee's study, where BMI was treated as a categorical variable during analysis, the results revealed an insignificant relationship between BMI and QoL (24). Further research is required to investigate the relationship between BMI and QoL since the relationship may not be linear (30) and a more complex relationship may be observed among older adults with different weight statuses. Sex was not found to significantly predict QoL profile membership in this study, which is consistent

with findings of a study on older adults in Iran (34), but differs from findings of further studies on older adults in other countries (31–33). Previous research has demonstrated that sex played a role in predicting QoL of older adults, with either men (31) or women (32) being significantly associated with higher QoL. It must be noted that the results of this study should be interpreted with caution because the number of men in the sample was relatively small. We submit that further research should be conducted in the future to explore this relationship by attempting to recruit more men to participate in the prospective studies.

Surprisingly, we did not observe any significant difference in the levels of cognitive impairment across the QoL profile, although a decrease was evident in participants of the Low QoL profile (reporting the lowest scores), while participants in the High QoL profile reported the highest scores. Although this result is inconsistent with previous findings, it is important to note that this is the first study to employ a person-centered approach to explore the association between QoL profile and cognitive impairment. We submit that further research should be conducted to explore the relationship between QoL and cognition using the same approach in a larger sample.

4.3. Limitations and future direction

To the best of our knowledge, this is the first study to investigate QoL profiles and their associations with predictors and outcomes using a person-centered approach among a sample of community-dwelling older adults in HK. Although this study contributes to the literature in the field of QoL research by providing new evidence using a person-centered approach, some limitations should be noted. First, the sample size was relatively small, although it was sufficient for statistical data analysis. Researchers are encouraged to investigate this research topic in the future using a larger sample, focusing on the need to recruit more men as participants. Second, data was collected in district community centers, this means we could only collect data from older adults who were willing to visit these centers regularly. In other words, the older adults who participated in this study may not best represent all older adults in Hong Kong and scholars should take care when trying to generalize our results. We submit that future researchers should consider alternative methods to recruit participants, such as cold calling and home visits in order obtain a more diverse sample. Third, relationships between socioeconomic and social vulnerability factors (e.g., education

attainment, marital status, and individual incomes) and QoL of older adults were not examined in this study, which is one of the limitations of the current study. Future researchers are encouraged to shed light on these research questions using person-centered approach, which will inform policy makings and practical works by providing tailor-made interventions or strategies in the future. Finally, this study has a cross-sectional design; thus, causal relationships among variables cannot be made. Future research should employ a longitudinal design using latent transition analysis to investigate changes in the latent profile of QoL over time and explore their longitudinal relationship with predictors and outcomes.

5. Conclusion

The findings of the current study add to the growing body of literature exploring QoL profiles and their associations with antecedent and outcome variables. The results of our study improve the extent and quality of what is known on the subject, supplementing the results of previous studies by utilizing a person-centered approach to examine the QoL profiles of community-dwelling older adults. Three distinctive QoL profiles emerged, and depression, but not sex, age, or BMI, was found to significantly predict profile membership. No significant differences in cognitive impairment were observed across the three profiles.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Hong Kong Baptist University. The participants provided their written informed consent to participate in this study.

Author contributions

J-DL: conceptualization and resources. GL, DW, YZ, and J-DL: methodology and formal analysis. WL, DW, XW, and YZ: validation. J-DL and YZ: investigation. GL, WL, YZ, and XW: data curation. GL and WL: writing–original draft preparation. J-DL and DW: writing–review and editing and supervision. All authors meet the criteria for authorship according to their contributions to the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Sex differences in the risk factors of disability among community-dwelling older adults with hypertension: Longitudinal results from the Health, Aging, and Retirement in Thailand study (HART)

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Background: Hypertension poses a serious health problem among Thai older adults which could subsequently lead to disability. However, little to no research has been conducted to understand modifiable risk factors of disability among community-dwelling older adults with hypertension in Thailand. In addition, sex is an important social determinant of health, but its role in disability among older adults with hypertension is less clear.

Objectives: This study focused on community-dwelling older adults with hypertension in Thailand and investigated predictors of disability and examined sex differences in the risk factors that were associated with disability in this population.

Methods: Longitudinal data were from the Health, Aging, and Retirement in Thailand (HART) survey (2015−2017; $N = 916$). The outcome variable was difficulty with the activity of daily living at follow-up. Potential risk factors included sociodemographic information, health behaviors/health status, and disability at baseline. Descriptive analysis and logistic regression analysis were employed to analyze the data.

Results: Most of the participants were female and between aged 60 and 69 years old. Being in an older age group (OR = 1.78, 95% CI: 1.07−2.97, $p < 0.05$), having more chronic conditions (OR = 1.38, 95% CI: 1.10−1.73, $p < 0.01$), experiencing obesity (OR = 2.02, 95% CI: 1.11−3.69, $p < 0.05$), and having disability at baseline (OR = 2.42, 95% CI: 1.09−5.37, $p < 0.05$) significantly predicted disability at 2 year follow-up among community-dwelling Thai older adults with hypertension. The effects of these risk factors on disability at follow-up did not differ by sex. However, different risk factors of disability were observed across sexes.

Conclusion: The situations of disability among older adults with hypertension in Thailand are likely to aggravate due to the rapid aging of the population. Our analysis provided useful information regarding significant predictors of disability and sex-specific risk factors of disability. Tailored promotion and prevention programs should be readily available to prevent disability among community-dwelling older adults with hypertension in Thailand.

Introduction

Disability is often defined as individuals' difficulties performing activities of daily living (ADL) such as bathing, toileting, and feeding as a result of physical or mental health conditions (1–4). The prevalence of such disability among older adults is nearly 38% worldwide, with a higher prevalence in low-income countries (43%) than in high-income countries (30%) (5). Disability in older individuals can have severe consequences, such as reduced physical activity (6) and increased risks of mental health problems (7). Disability also affects family members. Research shows that disability that occurs among family members can lead to financial insecurity in the family and that the cost of taking care of a disabled person increases with the severity of disability (8, 9). Several risk factors of disability among older adults have been identified in previous research. Being older (10–12) and female (10–13) are related to increased odds of disability. Compared to individuals who are married, those who are separated or divorced have higher risks of disability (11–13). Living in rural settings heightens the probability of having disability compared with living in urban settings (11, 12). Socioeconomic status (SES) can also affect the presence of disability. For example, older adults without education are more likely to be disabled compared to those who with some education. Older adults with a lower income level are more likely to be disabled compared to older adults with a higher income level (14). In terms of health behaviors/health status, such as poor vision or hearing (15, 16), poor self-rated health (3, 13, 14), drinking alcoholic beverage (14), having a lower level of physical exercise (12, 14), being overweight (3, 10, 12, 13), losing weight excessively (17), taking five or more medications (3, 13), having a slower gait speed (17, 18), feeling pain (13), having hypertension (6, 19), having at least one chronic condition (11, 12, 14, 15), and being depressed (3, 10, 12, 15) are risk factors of disability among older adults.

Hypertension is one of the most frequently reported chronic conditions among older adults, with over 50% of older adults with this condition globally (20–25). Older adults with hypertension may be more likely to become disabled because hypertension can influence individuals' physical performances [e.g., poor performance on gait speed and balance (26), an accelerated decline of handgrip strength (27), and a poor postural control that increases risks of falling (28)], which can subsequently increase difficulty with performing daily activities. Previous evidence also supports such notion. Studies have shown that hypertension can increase the odds of having a disability, with about one in eight adults with hypertension having disability (20, 21). In addition, evidence also reveals that the chance of developing disability among individuals with hypertension increases with age. For instance, in one study, the researchers found that individuals aged 60 years or above had higher odds of having disability by 1.5 times compared to those aged between 45 and 59 years old (19). Currently, several studies have been conducted to understand disability among older adults with hypertension (19–21). However, research has shown that even at a similar economical level, the prevalence of disability can vary across countries (29). For instance, the estimated prevalence of disability among older adults in low-income countries was 24.9% in Cameroon, 22.4% in Guatemala, 39.2% in India, 9.7% in Nepal,

and 29.4% in Maldives (29). Such variance stresses the importance of country-specific investigations.

This study focused on disability among older adults with hypertension in Thailand—a developing country with an upper-middle-income economy. Nearly 19% of Thailand's population are adults aged 60 years or above in 2019, but the proportion of older adults is expected to increase rapidly by 17% from 2019 to 2050 (30). Hypertension has been the most prevalent chronic condition among older adults in Thailand (31). Because advanced age not only increases the chances of having hypertension (32) but also heightens the risks of developing disability among individuals with hypertension (19), a better understanding of factors that are associated with disability among older adults with hypertension in Thailand is needed to provide evidence-based recommendations to the Thai government.

Four studies, to date, have been conducted to understand disability among older adults in Thailand (11, 33–35). However, only two studies find significant relationship between hypertension and disability (11, 35). These studies are limited because they employ a cross-sectional design. In addition, none of them focus on the population of older adults with hypertension. To address this gap, the first goal of this study was to conduct a longitudinal investigation on the risk factors of disability among Thai older adults with hypertension.

Another aspect of disability that remains unclear is the role of sex. Although there is a higher prevalence of self-reported disability [assessed by difficulty with activities of daily living (ADL)] among older females than males (11, 12, 36, 37), several studies have shown no effects of sex on ADL disability (6, 13, 38). Because disability may differ by health conditions (20, 39) and sex (11, 12, 36, 37), a better understanding of sex disparity in disability among older adults with hypertension is warranted. Hence, the second goal of this study was to further examine the relationship between sex and disability and investigate whether risk factors associated with disability differed by sex.

Materials and methods

Data

Longitudinal data were from the HART (40), a study that consisted of nationally representative sample of adults aged 45 year old and over. The data are available for academic users from the website of the Center for Aging Society Research (CASR), NIDA, Thailand at http://rc-demo.nida.ac.th/casr/. We used data from 2015 (served as baseline) and 2017 (served as follow-up). Among the original sample ($N = 5,616$) at baseline, 3,718 individuals completed follow-up survey. The final sample size was 916 individuals after excluding individuals who were younger than 60 years old at baseline ($n = 1,788$), did not have hypertension at baseline ($n = 2,229$), and had missing data on key variables in both waves ($n = 683$). Compared to those who were excluded ($n = 4,700$), no significant differences were observed in baseline age ($X^2(4, N = 916) = 4.91, p = 0.297$), sex ($X^2(1, N = 916) = 0.12, p = 0.725$), and education ($X^2(1, N = 916) = 1.86, p = 0.173$) in the current sample.

Measures

Outcome variable: disability at follow-up

During the HART interview, participants were asked whether they had difficulties with the following activities of daily living (ADL) in the past week: Dressing, grooming, bathing, and eating. The responses included "able to do it all by myself," "need helps sometimes or some steps," "always need help in some steps," and "need helps for all steps." Individuals whose response was "need help sometimes or some steps," "always need help in some steps," or "need helps for all steps" were considered as having difficulty. Two additional questions were asked in the survey to assess whether participants experienced incontinence of bladder and bowel. The responses included "yes, all the time," "yes, more than 15 days a month," "yes, 5–15 days a month," "yes, no more than 5 days a month," and "no." Individuals whose response was "yes" to incontinence were considered as having difficulty. Disability was conceptualized as any difficulty with performing activities of daily living (ADL). A dummy variable for disability was created with 1 indicating individuals with any difficulty with ADL, otherwise no difficulty (coded as 0).

Potential risk factors at baseline

Potential risk factors were selected based on factors that were related to disability. These included *sociodemographic information* [i.e., age (10–12), sex (10–13), education (14), marital status (11–13)], *health behaviors and health status* [i.e., taking hypertension medication (3, 13), chronic conditions (11, 12, 14, 15), self-rated physical health (3, 13, 14), smoking, drinking (14), exercise frequency (12, 14, 17), body mass index (BMI) (3, 10, 12, 13, 17), number of pain locations (13), any hearing impairment (16), any visual impairment (15, 16), and depressive symptoms (3, 10, 12, 15)].

Sociodemographic information

Age was assessed by asking participants "*How old are you*?" The responses were categorized into three age groups: 60–69 years old (reference group), 70–79 years old, and 80 years or above. Sex is classified as male (0) and female (1). Education was measured by asking respondents "*What is your highest level of education?*" The responses were from 1 (No formal education) to 8 (Higher than a bachelor's degree). We coded primary school or lower as 0 and secondary school or above as 1. Marital status was coded as married (1) and not married (0).

Health behaviors and health status

Taking hypertension medication was assessed by asking "*Are you receiving any treatment or taking any hypertension medication?*" The response was yes/no. We coded 1 for "yes" and 0 for "no."

Chronic conditions were assessed by asking participants if they had been diagnosed by a doctor with the following chronic conditions: Diabetes, vascular diseases, rheumatism/arthritis, diseases of the bone, kidney diseases, lung diseases, brain cancer, and other cancer. A positive response endorsed a chronic condition. The total number of chronic conditions ranged from 0 to 8.

Self-rated physical health was measured by asking "*In general, how would you rate your physical health status?*" Participants were asked to score on a scale from 1 to 100. A higher score means worse health.

Smoking was measured by asking "*Have you ever smoked cigarettes?*" The responses were "yes, and still smoke now," "yes, but already quit smoking," and "never." We coded 1 for current smokers (yes, and still smoke now) and 0 for not current smokers ("yes, but already quit smoking" or "never").

Drinking was measured by asking "*Have you ever drunk alcoholic beverages such as liquor, beer or wine*?" The responses were "yes, and still drinking now," "yes, but already stopped drinking," and "never." We coded 1 for current drinkers (yes, and still drinking now) and 0 for not current drinkers ("yes, but already stopped drinking" or "never").

Exercise frequency was measured by asking "*How often do you exercise?*" The responses were from 1 (7 days a week) to 5 (never). We reversed the coding, such that a higher number indicates more frequent physical exercise.

Body Mass Index (BMI) was calculated by using self-reported weight (in kilograms) divided by squared height (in meters). Individuals were then categorized as underweight (<18.5 kg/m^2), normal weight (18.50–24.9 kg/m^2; reference group), overweight (25.0–29.9 kg/m^2), or obese (>30 kg/m^2).

Number of pain locations was assessed by asking individuals to rate their pain on a 4-point scale (no, mild, moderate, and severe pain) in the last month for the following locations: head, shoulder, arms, wrist, fingers, chest, stomach, back, hips, legs, knees, ankles, and toes. Individuals responded mild, moderate, or severe pain were considered as having pain. We summed up all locations for respondents and created a 3-category variable: no pain (reference), one location, and multiple pain location.

Any hearing problems was assessed by asking "Have you ever been diagnosed with the following hearing conditions: hearing loss (one ear), hearing loss (both ears), auditory hallucination, tinnitus, inner ear fluid abnormality, others?" The responses were "yes" and "no." An endorsement to any of these conditions was considered poor hearing and coded as 1, otherwise 0.

Any visual problems was assessed by asking "Have you ever been diagnosed with the following visual conditions: blind one eye, blind two eyes, myopia, hypermetropia, astigmatism, glaucoma, cataract, pterygium, dry eye/xerophthalmia, others?" An endorsement to any of these conditions was considered poor vision and coded as 1, otherwise 0.

Depressive symptoms were assessed with the 10-item Center for Epidemiologic Studies Depression Scale (41). We followed standardized procedure to calculate scores. Total scores were from 0 to 30.

Data analysis

Descriptive statistics were employed to describe sample characteristics. Univariate logistic regression analysis was used to investigate the association between each potential risk factor at baseline and disability at follow-up. Significant risk factors found in univariate logistic regression analysis were then entered in multiple

TABLE 1 Characteristics of participants.

	All participants (N = 916)
	Mean (SD) or N (%)
Female (yes)	552 (60.26)
Interview method	
Face-to-face interview	916 (100)
Age groups	
60–69 years old	362 (39.52)
70–79 years old	332 (35.15)
80 years old or above	232 (25.33)
Education	
Primary school or lower	858 (93.67)
Secondary school or above	58 (6.33)
Married (yes)	455 (49.67)
Taking hypertension medication (yes)	814 (88.96)
Chronic conditions (0–8)	0.59 (0.76)
Number of pain locations	
No pain	263 (28.71)
One location	325 (35.48)
Multiple pain locations	328 (35.81)
Depressive symptoms (0–30)	6.42 (3.57)
Self-rated physical health (1–100; higher is worse)	4.17 (1.53)
Smoking (yes)	132 (14.41)
Alcohol (yes)	132 (14.19)
Exercise frequency	1.08 (1.37)
Body mass index	
<18.5 kg/m^2	98 (10.70)
Between 18.50 and 24.9 kg/m^2	476 (51.97)
Overweight between 25.0 and 29.9 kg/m^2	258 (28.17)
Obese > 30 kg/m^2	84 (9.17)
Any visual impairment (yes)	93 (10.15)
Any hearing impairment (yes)	3 (3.28)
ADL difficulty at baseline	
Dressing at baseline (yes)	29 (3.17)
Grooming at baseline (yes)	26 (2.84)
Bathing at baseline (yes)	26 (2.84)
Eating at baseline (yes)	26 (2.84)
Incontinence at baseline (yes)	58 (6.33)
Any disability at baseline (yes)	31 (3.38)
ADL difficulty at follow-up	
Dressing at follow-up (yes)	58 (6.33)
Grooming at follow-up (yes)	42 (4.59)

(Continued)

TABLE 1 (Continued)

	All participants (N = 916)
	Mean (SD) or N (%)
Bathing at follow-up (yes)	39 (4.26)
Eating at follow-up (yes)	29 (3.17)
Incontinence at follow-up (yes)	93 (10.15)
Any Disability at follow-up (yes)	136 (14.85)

logistic regression analysis to investigate baseline independent risk factors of disability at follow-up among community-dwelling Thai older adults with hypertension. To investigate sex disparity in the association of risk factors at baseline with disability at follow-up, we performed moderation analysis and sex-stratified analysis. Regarding moderation analysis, in the multiple logistic regression analysis model, an interaction term between each risk factor and sex was entered one at a time. In sex-stratified analyses, within each sex group, we followed similar steps to identify significant risk factors using univariate logistic regression analysis and then entered them simultaneously in a multiple logistic regression analysis. Stata version 15 (Stata Corp LLC, College Station, TX, USA) was used to perform data. This secondary data analysis was approved by the ethics review board at Taipei Medical University (TMU-JIRB: N202304033).

Results

Table 1 shows sample characteristics at baseline. Among participants with hypertension at baseline, nearly 4% reported any disability at the baseline, and it was about 14.85% at follow-up. Most participants were female, between aged 60–69 years old, and had an education level of primary school or lower. Nearly 50% of the respondents were married. There were approximately 89% of the participants taking hypertension medication.

The association of risk factors at baseline with disability at follow-up

Table 2 provides information from the univariate logistic regression analyses assessing the relationship between risk factors and disability among older adults with hypertension in Thailand. Overall, the results showed that being female, being at an older age group, having more chronic conditions, having poor self-rated physical health, using alcohol, being obese, and experiencing disability at baseline were significantly associated with disability at follow-up. These significant variables were next entered into multiple logistic regression analysis to investigate independent risk factors at baseline of disability at follow-up.

Table 3 presents the results from the multiple logistic regression analysis. The results showed that being in the age group 80 years

TABLE 2 Univariate logistic regression analysis examining the relationship between baseline risk factors and disability at follow-up among community-dwelling older adults with hypertension in Thailand.

	Disability at follow-up (N = 916)		
	No disability	Disability	Odds ratio (95% confidence interval)
	Mean (SD) or N (%)		
Female (yes)	459 (83.15)	93 (16.85)	1.51 (1.03–2.23)*
Age groups			
60–69 years old	324 (89.50)	38 (10.5)	ref
70–79 years old	271 (84.16)	51 (15.84)	1.61 (1.02–2.52)*
80 years old or above	185 (79.74)	47 (20.26)	2.17 (1.36–3.45)**
Education			
Primary school or lower	752 (84.85)	130 (15.15)	ref
Secondary school or above	52 (89.66)	6 (10.34)	0.65 (0.27–1.54)
Married (yes)	397 (87.25)	58 (12.75)	0.72 (0.50–1.04)
Taking hypertension medication (yes)	694 (85.26)	120 (14.74)	0.93 (0.53–1.64)
Chronic conditions (0–8)	0.53 (0.71)	0.80 (0.89)	1.50 (1.20–1.85)**
Number of pain locations			
No pain	225 (85.55)	38 (14.45)	ref
One location	282 (86.77)	43 (13.23)	0.90 (0.56–1.44)
Multiple pain locations	273 (83.23)	55 (16.77)	1.19 (0.76–1.87)
Depressive symptoms (0–30)	6.47 (3.55)	6.91 (3.81)	1.04 (0.99–1.09)
Self-rated physical health (1–100; higher is worse)	4.14 (1.52)	4.61 (15.72)	1.21 (1.07–1.36)**
Smoking (yes)	114 (86.36)	18 (13.64)	0.89 (0.52–1.52)
Drinking (yes)	120 (92.31)	10 (7.69)	0.44 (0.22–0.86)*
Exercise frequency	1.08 (1.38)	1.08 (1.47)	1.00 (0.87–1.14)
Body mass index			
<18.5 kg/m^2	78 (79.59)	20 (20.41)	1.74 (1.00–3.05)
Between 18.50 and 24.9 kg/m^2	415 (87.18)	61 (12.82)	ref
Overweight between 25.0 and 29.9 kg/m^2	223 (86.43)	35 (13.57)	1.07 (0.68–1.67)
Obese > 30 kg/m^2	64 (76.19)	20 (23.81)	2.12 (1.21–3.76)**
Any visual impairment (yes)	78 (83.87)	15 (16.13)	1.12 (0.62–2.00)
Any hearing impairment (yes)	27 (90.00)	3 (10.00)	0.63 (0.18–2.10)
Disability at baseline (yes)	19 (61.29)	12 (38.71)	3.88 (1.84–8.18)**

*The significant value of p < 0.05. **The significant value of p < 0.01.

old or above (OR = 1.78, 95% CI: 1.07–2.97), having chronic conditions (OR = 1.38, 95% CI: 1.10–1.73), being obese (OR = 2.02, 95% CI: 1.11–3.69), and disability at baseline (OR = 2.42, 95% CI: 1.09–5.37). Specifically, compared to individuals who were between 60 and 69 years old at baseline, those aged 80 or above had increased risks of being disable at follow-up by 78%. Having one additional chronic disease at baseline increased the odds of being disable by 38%. Compared to individuals with normal weight, those with obesity at baseline were twice more likely to be disable later. Compared to individuals without disability at baseline, those who were disabled were approximately 2.5 times more likely to report disability at follow-up.

The role of sex in the relationship between baseline risk factors and disability at follow-up

The prevalence of disability was 0.98% among males and 2.40% among females at baseline. In moderation analysis, there was no significant interaction terms between sex and risk factors (i.e., age groups, chronic conditions, self-rated physical health, drinking, body mass index, and disability at baseline) at baseline on disability at follow-up (Supplementary Table 1). These results suggest that these factors work in a similar manner between sexes among community-dwelling Thai older adults with hypertension.

TABLE 3 Multiple logistic regression analysis investigating independent risk factors at baseline of disability at follow-up among community-dwelling older adults with hypertension in Thailand.

	All participants (N = 916)
	Odds ratio (95% confidence interval)
Female (yes)	1.22 (0.79–1.87)
Age groups	
60–69 years old	ref
70–79 years old	1.48 (0.92–2.37)
80 years old or above	1.78 (1.07–2.97)*
Chronic conditions (0–8)	1.38 (1.10–1.73)**
Self-rated physical health (1–100; higher is worse)	1.13 (0.99–1.27)
Drinking (yes)	0.52 (0.25–1.08)
Body mass index	
<18.5 kg/m^2	1.50 (0.83–2.68)
Between 18.50 and 24.9 kg/m^2	ref
Overweight between 25.0 and 29.9 kg/m^2	1.06 (0.67–1.68)
Obese > 30 kg/m^2	2.02 (1.11–3.69)*
Disability at baseline (yes)	2.42 (1.09–5.37)*

*The significant value of $p < 0.05$. **The significant value of $p < 0.01$.

TABLE 4 Stratified analysis examining significant risk factors at baseline associated with disability at follow-up among community-dwelling older adults with hypertension in Thailand.

	All participants (N = 916) Odds ratio (95% confidence interval)	
	Male	Female
Age groups		
60–69 years old		Ref
70–79 years old		1.74 (0.97–3.13)
80 years old or above		2.90 (1.55–5.45)**
Chronic conditions (0–8)		1.49 (1.12–1.99)**
Self-rated physical health (1–100; higher is worse)	1.37 (1.10–1.69)**	1.02 (0.88–1.19)
Body mass index		
<18.5 kg/m^2		1.30 (0.62–2.73)
Between 18.50 and 24.9 kg/m^2		Ref
Overweight between 25.0 and 29.9 kg/m^2		1.07 (0.60–1.89)
Obese > 30 kg/m^2		2.49 (1.23–5.05)*
Disability at baseline (yes)	2.65 (0.59–11.79)	2.11 (0.82–5.41)

*The significant value of $p < 0.05$. **The significant value of $p < 0.01$.

Differential risk factors of disability emerged in sex-stratified analyses. Among males, self-rated physical health and disability at baseline were significantly related to disability at follow-up in the univariate logistic analysis (Supplementary Table 2). Only self-rated physical health (OR = 1.37, 95% CI: 1.10–1.69) remained significant in the multiple logistic regression analysis (Table 4). Specifically, having one score higher on self-rated physical health at the baseline was associated with increased risks of being disable at follow-up by 37%. Among females, being in the age group of 70–79 and 80 years old or above, having chronic conditions, being obese, and disability at baseline were significantly related to disability at follow-up in the univariate logistic analysis. In the multiple logistic regression analysis, significant risk factors were being in the age group 80 years old or above (OR = 2.90, 95% CI: 1.55–5.45), having chronic conditions (OR = 1.49, 95% CI: 1.12–1.99), and being obese (OR = 2.49, 95% CI: 1.23–5.05). Specifically, compared to individuals who were between 60 and 69 years old at baseline, those aged 80 or above had increased risks of being disable at follow-up by almost three times. Having one additional chronic disease at baseline increased the odds of being disable by 49%. Being obese at baseline increased the risks of having disability at follow-up by 2.5 times compared to normal weight.

Discussion

This study investigated predictors of disability among community-dwelling older adults with hypertension in Thailand. We found that being 80 years old or over, and having more chronic conditions, being obese, and experiencing disability at baseline were significant predictors of disability at 2 year follow-up among community-dwelling older adults with hypertension in Thailand. We also investigated the role of sex in the relationship between risk factors at baseline and disability at follow-up. We did not find any significant interaction effects between sex and risk factors at baseline on disability at follow-up, suggesting that the effects of baseline risk factors on disability at follow-up were similar across sexes. However, significant risk factors at baseline of disability at follow-up were different within each sex group. Poor self-rated health was a significant predictor among older Thai men with hypertension. An advanced age, having more chronic conditions, and being obese were significant predictors among older Thai women with hypertension.

To the best of our knowledge, this is the first study investigating disability among older adults with hypertension in Thailand. Although similar research has been conducted in India (21), Taiwan (20), and China (19), each study has different objectives. For instance, the study from India investigated the prevalence of disability and non-communicable diseases (21), the study from Taiwan investigated the effects of chronic conditions on the experiencing of disability (20), and the study from China examined the relationship between comorbid conditions and the experiences of disability among older adults with hypertension (19). Hence, our study contributes to the literature by demonstrating the predictors of disability among older adults with hypertension.

We found that an older age was a significant predictor of disability in Thai older adults with hypertension. This finding is consistent with previous findings (19–21). One possibility is that advanced age is associated with a higher probability of deterioration of physical health (e.g., poor performance on gait speed and balance), which then limit the performance of ADL.

For instance, research has shown that endothelial dysfunction is associated with frailty and sarcopenia (42), and advanced age among individuals with hypertension can worsen already existed endothelial dysfunction (42–44). Another study demonstrated that there is association between poorer cerebral perfusion with slower gait speed among adults with advanced age (45). The underlying mechanisms for older ages and disability among older adults with hypertension could be multidimensional and warrant further investigations.

Previous studies have linked obesity to disability among older adult population (3, 10, 12, 13). Our findings added to the literature by showing that obesity significantly predicted disability among older adults with hypertension. Previous studies have shown that hypertension is the main health condition associated with obesity (46) and that individuals with obesity-related hypertension had a higher prevalence of other diseases (e.g., diabetes mellitus and hyperuricemia) (47) and disability (48) compared to individuals with non-obesity-related hypertension (47). Hence, weight management is crucial for disability prevention among older adults with hypertension.

Being consistent with previous research (11, 12, 14, 15), we found that having one additional chronic condition beyond hypertension increased the odds of having disability at follow-up by 38%. However, the combination of chronic conditions may affect the probability of having disability. For instance, a previous study showed that hypertension existed in most of the combinations of multimorbidity and that the combination of hypertension, depressive symptoms, and arthritis had the strongest association with disability than other combinations among older adults in the United States (49). Such findings suggest specific health conditions co-exist with hypertension may have higher chances to result in disability among older adults. More investigations on the association of the combination of hypertension and other chronic conditions with disability among older adults in Thailand are warranted.

We found that nearly 15% of the respondents had disability at baseline, and such experience determined the experience of disability at 2-year follow-up. Although most disability may recover within the following 6 months of the onset, a significant proportion recovers in the subsequent 2 years (50). Nevertheless, one study found that baseline disability remained to be a significant predictor of disability at 3 year follow-up (6). Such discrepancy in time lag and how disability recovers need further investigation to help identify a better timing for the provision of intervention on disability among individuals with hypertension.

Our findings have practical implications. This study provides information regarding predictors of disability among community-dwelling Thai older adults with hypertension across sexes and within each sex group. Such information can be used by government and agencies to develop programs aiming to delay disability among community-dwelling older adults with hypertension in Thailand. Preventive programs (e.g., home and environment modifications for individuals who are already disable) targeting the high-risk groups (i.e., 80 years or above) are important. Continued efforts to deter the development of additional chronic disease, manage obesity, and improve disability may also help prevent disability among older adults

with hypertension. Furthermore, given the existence of sex disparity in the risk factors of disability, program planners should also take these sex-specific factors into account to develop preventive strategies.

Strengths and limitations of this study

The strength of this study was the use of longitudinal data from a nationally representative sample of Thai older adults. There are limitations in this study. First, we analyzed self-reported data from the HART, which may be affected by common measure bias. Second, the HART only focuses on ADL. Hence, we are unable to estimate the prevalence of difficulty with instrumental activities of daily living and investigate their related risk factors. Last, the data are from Thai older adults with hypertension. The findings can be only generalized to this segment of population.

Conclusion

The prevalence of disability among community-dwelling older adults with hypertension is expected to soar due to a rapidly aging population in Thailand. Our study provides the first glance of disability among community-dwelling older adults with hypertension in Thailand. The main findings are as follows: (1) The oldest aged group (80 years old and above), chronic conditions, disability at baseline, and obesity are the leading risk factors at baseline associated with disability at 2 year follow-up among older adults with hypertension in Thailand, (2) the effects of risk factors at baseline on disability at follow-up are similar across sexes, and (3) an advanced age, having more chronic conditions, and being obese were significant predictors among older Thai women with hypertension, while poor self-rated health and having disability at baseline associated with disability for older Thai men with hypertension. Therefore, customized promotion and prevention programs (i.e., healthy diet, health behavior modification to prevent obesity and chronic conditions) to promote independence among older adults with hypertension in Thailand are a pressing issue that needs to be addressed and organized to provide effective services for this targeted population.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: Center for Aging Society Research (CASR), The National Institute of Development Administration (NIDA), Thailand (http://rc-demo.nida.ac.th/casr/).

Ethics statement

The studies involving human participants were reviewed and approved by the Ethical Review Board at Taipei Medical University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

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.2023.1177476/full#supplementary-material

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The impact of older adult care policy mixes on the construction of senior centers

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The problem of an aging population is becoming increasingly serious, and the establishment of senior centers helps to promote the physical health and mental health of the older adult, a key factor in achieving the high-quality development of the old-age security industry. The government has issued a number of policies to promote the establishment and development of senior centers. However, more and more older adult care policy mixes have gradually shown the phenomenon of poor policy connection, confusing standards, and even mutually exclusive content, resulting in many problems in the construction of policy-driven senior centers. Therefore, based on the overall perspective of the older adult care policy mix, this paper uses the GMM method to explore the impact of the comprehensiveness, balance, and consistency of older adult care policy tool portfolios issued by Chinese government agencies on the construction of senior centers in China. The empirical analysis results show that a comprehensive and consistent policy mix can promote the establishment of senior centers, while the balance of the policy mix will inhibit the establishment of senior centers. This paper analyzes the impact of older adult care policy on the construction of senior centers from the perspective of the policy mix, which helps to clarify the different policy effects produced by different policy mix characteristics and provides feasible policy suggestions for the government to formulate more reasonable and effective policies.

KEYWORDS

older adult care policy mix, comprehensiveness, consistency, balance, senior center

1. Introduction

As of the end of 2021, China's older adult population aged 60 and above totaled 267.36 million, accounting for 18.9% of the total population. The national older adult population aged 65 and above is 200.56 million, accounting for 14.2% of the total population, and the older adult population is about to enter deep aging. In recent years, China's aging rate has continued to rise. Compared with 2010, the aging rate has increased by 5.44 percentage points, and the phenomenon of social aging has become increasingly serious (1, 2). How to promote the physical and mental health development of the older adult has become an extremely important research question, and received widespread attention (3, 4). As an important aspect of the construction of older adult service facilities (2), the construction of senior centers can not only effectively meet the needs of the older adult for basic life, basic medical care, and basic security, but also provide cultural, friendship, entertainment, and leisure services. It is an important means of promoting the physical and mental health development of the older adult and ultimately the high-quality development of China's older adult care service system (5, 6). An older adult care activity center refers to a special institution and place with a certain scale that provides comprehensive cultural and recreational activities for the older adult, and its functional core

includes the following two parts: (1) entertainment and rest for the older adult and (2) auxiliary functions such as catering, medical care, management, and other aspects (7). Building more senior centers can help promote the physical health and mental health of the older adult, help to cope with the challenges of aging, and achieve healthy aging (8).

The construction of senior centers requires much resources, and there are problems such as high upfront investment costs and the time it takes to see a return on funding (4, 9). In addition, the public has insufficient confidence in the social pension industry. This has led to an over-reliance on market investment resources to build senior centers. These resources are not sufficient to meet China's growing demand for older adult care services (10, 11). Therefore, to accelerate the development of the physical and mental health of the older adult and the high-quality development of the older adult service system, the Chinese government has successively promulgated a series of relevant policies for the older adult, such as financial subsidies, tax exemptions, and standardized construction standards (2). These policies promote the construction of senior centers. However, the result of the promulgation of a large number of policies related to the older adult is that policies issued by governments at all levels have formed a combination of older adult care policies. The problems of large policy range, inconsistent goals, and ambiguous planning in the combination of older adult care policies are not conducive to promoting the flow of social resources to the construction of senior centers. In summary, in order to accelerate the construction of senior centers and promote the construction of an age-friendly society, it is necessary to explore the influence mechanism of the characteristics of the existing older adult care policy mix on the construction of senior centers, to help government departments formulate more accurate and effective policies, and ultimately achieve the high-quality development of China's older adult care service system.

Thus, in order to better promote high-quality living for the older adult, this paper aims to give useful policy suggestions to policy makers by analyzing the policies related to older adult care services promulgated by the State Council and various ministries and commissions of the State Council from 2011 to 2019. This paper explores the specific impact of the comprehensiveness, balance, and consistency of the older adult care policy mix on the construction of senior centers in various regions of China. Following prior research, we divided the older adult care policy mix instrument into the following three categories: supply-based, demand-based, and environmental-based older adult care service policy instruments (2, 12). Then, we built statistical models to investigate the influence of policy mix characteristics on the construction of senior centers. The empirical analysis results show that the comprehensiveness and consistency of the older adult care policy mix can promote the construction of the senior centers, while the balance of the older adult care policy mix may inhibit the construction of the senior centers.

Our paper makes several contributions. The research conclusions of this paper are helpful in clarifying the effectiveness of China's existing older adult care policies, identifying the aspects to be improved, and providing a theoretical basis for government departments to formulate more accurate and effective policies in the future, and then give full play to the combination of policy tools. However, in the existing policy mix, there is an interaction between a single policy, and there are differences in the impact of the comprehensiveness, consistency, and balance of the older adult care

policy mix on the construction of senior centers. The characteristics of the policies play significant roles in promoting the high-quality development of China's old-age service system.

2. Literature review and hypothesis

2.1. Older adult care policy mix literature

For China, in the context of the transition economy, the role of the government in promoting old-age security is extremely critical, and the old-age-related policies formulated by government agencies will affect the resource investment of social organizations in the old-age security industry, such as the establishment of more senior centers, the provision of more beds, and the establishment of more business organizations aimed at improving the quality of life of the older adult (2, 13). Studies have pointed out that old-age policies will have an impact on the resource investment of the old-age security industry. However, most of the existing studies regard older adult care policies as homogeneous policies, ignoring the great differences between older adult care policies. Multiple older adult care policies together form an older adult care policy mix, and there are often interactions between multiple policies in the policy mix, and there are differences or even contradictions between policies, factors that have a differential impact on policy outcomes (14–16).

Scholars have proposed that the overall effect of different policy mixes is different, there are differences in policy mixes in pension resource investment in different regions, and the impact of the same policy mix in different regions is also different (2, 17). In the analysis of the effective impact of policy mix, scholars have pointed out that clarifying the characteristics of policy mix is a prerequisite for better understanding and evaluating the effect of a policy mix (18). The government's older adult care policy mix is characterized by investment in older adult care resources and the construction of senior centers.

In order to deeply understand the characteristics of the older adult policy mix, it is important to describe the differences and nature of different policies. Existing literature has pointed out that comprehensiveness, balance, and consistency are the most important characteristics of the policy mix (19–21). These characteristics may play different roles in affecting the efficiency and effectiveness of the policy mix.

However, there is little research on the impact of older adult care policy on old-age security in the existing policy mix literature, and there is a lack of analysis of the characteristics of the policy mix, such as the impact of the most important policy mix on the investment of pension resources. Clarifying the effects of different characteristics of the older adult policy mix on older adult resource input can help make related policies better, thereby improving the quality of old-age security.

2.2. Hypothesis

Policy tools are the practical means and methods adopted by policymakers to achieve set policy goals. Some scholars have pointed out that policy mix refers to the combination of different policy instruments, and the interaction between policy instruments is the

basis of policy mix. Some scholars have classified policy tools into the following four categories: regulatory instruments, economic instruments, financial instruments, and soft instruments (22). Other scholars divide the policy mix instruments into categories such as mandatory, market, information transmission, and voluntary (23). In our study, when dividing the older adult policy mix, we follow the framework proposed by Rothwell and Zegveld (12). We divide the policy mix instruments into environmental, supply-based, and demand-oriented policy instruments (2, 24). Supply-based policy instruments include effective support in terms of funds, facilities, technology and information. Demand-oriented policy instruments include service outsourcing, direct procurement, international exchanges, and trade regulation. Environmental policy instruments can provide a favorable policy environment through using tax incentives, regulatory controls and strategic measures.

Based on the older adult care policies collected in this paper, and on the results of the text-mining method, we further analyzed the diversified older adult care policy tools involved in multiple older adult care policies. The specific content involved in environmental policy tools, supply-oriented policy tools, and demand-oriented policy tools were further analyzed, and the keywords were analyzed and identified separately. Based on Zhang's (2) research, Table 1 shows the specific classification of older adult care policy tools and the description of content keywords.

2.2.1. The influence of comprehensive older adult care policy mixes on the number of senior centers

The comprehensive combination of older adult care policies measures the breadth of policy application. Therefore, to promote the effectiveness of pension security, a variety of policy instruments will be used comprehensively. The comprehensive measurement of the comprehensiveness and diversity of older adult care policy tools, and the combination of policies have a degree of complexity. The use of a wide range of policies can more effectively activate policy departments at all levels and can incentivize other organizations to contribute to the security

of the older adult, helping to provide a good environment for promoting the physical and mental health of the older adult. The stronger the comprehensiveness, the more types of policy tools involved in the older adult care policy mix, and the more detailed the policy objectives formulated.

For example, in terms of the comprehensive use of older adult care policy tools, the government has issued a series of policies to promote the development of the pension security industry, such as promoting the introduction of pension equipment, platforms, system construction, pension institution construction incentives, tax exemptions, and other policy mixes. The improvement in the breadth of the older adult care policy mix can promote the development of the pension security industry and the promotion of the high-quality development of the care of the older adult to provide more favorable conditions.

In short, adopting a variety of policy tools can improve policy effectiveness. The government can accelerate the investment of more resources in the construction of older adult care centers by combining multiple tools in society (25), thereby improving the promotion of the healthy development of the older adult care industry. Zhang's (2) research also points out that the comprehensive combination of older adult care policies can promote the growth of the number of older adult care resource beds. Therefore, we propose the following hypothesis:

> *Hypothesis 1*: The comprehensiveness of policy tools (demand, supply, environment) of older adult care policy can positively promote the number of senior centers.

The balance of the older adult care policy mix measures the difference between the intensity and development level of different policies in the older adult care policy mix (26). The balance of intensity and development level between policies is conducive to promoting the healthy development of old-age security. The implementation of a balanced policy mix helps to form a more reliable and stable policy framework, which helps to enhance the confidence of social organizations in the investment of the older adult care industry,

TABLE 1 Classification of policy instruments and description of their contents.

Type of policy instrument	Content	Keyword
Demand Policy	Government procurement	The government buys equipment, services
	Service outsourcing	Social capital
	Nurturing the market	Market development, growth
	International demand	Enhance international cooperation and exchanges
Supply policy	Talent development	Education and training, project investment
	Capital investment	Funding, resources, and capital investment
	Technology investment	Technology research and development, innovation
	Facility input	Supporting facilities, aging transformation
	Information Services	Digital platform, information exchange
Environmental Policy	Tax benefits	Tax deductions
	Technical support	Industry–university research cooperation, alliance cooperation
	Land policy	Venue rent reduction
	Administrative measures	Streamline the approval process
	Other economic policies	Utility fee waiver

thereby promoting a willingness to build more activity centers for the older adult. Conversely, the use of only one policy tool often cannot meet the complex social environment needed to promote the investment of pension resources into the construction of senior centers. If it were possible to combine the advantages of a variety of different types of policy tools, while avoiding their disadvantages, it would greatly enhance the policy effect.

However, unlike the demands of eating, drinking, and medical treatment to meet the basic living security of the older adult, the purpose of the construction of a senior center is to promote the physical and mental health of the older adult and to simultaneously promote the healthy development of the older adult (27). If the older adult care policy is too balanced and there is no special attention paid to the construction of the senior center, then under normal circumstances, the pension resources are more likely to be allocated to meet the basic needs of the older adult in terms of eating, drinking, and medical treatment. Therefore, the balance of policy mix is not conducive to the construction of senior centers. Therefore, we propose the following hypothesis:

> *Hypothesis 2*: The balance of older adult care policy mix policy tools (demand, supply, environment) can positively promote the number of senior centers.

The consistency of the older adult care policy mix measures the synergy between policies within the policy mix and reflects the differences between policies. There are fewer conflicts between policies within a highly consistent policy mix; there is even some synergy. The consistency and coordination between policies can provide a good institutional environment for the investment of social pension resources and the construction of senior centers and can more effectively promote the high-quality development of the older adult care industry (28). The impact of a single science and technology policy on promoting old-age security is limited, so the government often promulgates a variety of policy tools or policy objectives to achieve a combination of different policies through coordinated allocation to give full play to the advantages of the policy mix more effectively. Coherence between policies in the policy mix can amplify policy effectiveness to a greater extent and promote the effectiveness and accessibility of care policies (29). For example, some policies emphasize that a variety of tax relief policies for the construction of senior centers will help promote their construction. Based on different demands, there are sometimes conflicts between policies formulated by different government agencies, thereby reducing the consistency of the older adult care policy mix and not being conducive to the construction of senior centers. Based on the above, we propose the following hypothesis:

> *Hypothesis 3*: The consistency of older adult care policy mix policy tools (demand, supply, environment) can positively promote the number of senior centers.

3. Sample and methods

3.1. Data collection

This paper selects the relevant policy documents of the State Council and various ministries and commissions from 2011 to 2019

for quantitative analysis of their text. Following prior literature (2), the relevent policies are derived from the following sections, respectively as: official websites of the State Council, various ministries and commissions of the State Council, and the legal database of Peking University, the most recognized database in China. In order to screen out policies closely related to the research topic of this study, we only keep the policies that contain the following terms: "old-age security," "home-based care," "community care," "medical and older adult care integration," "pension system," "smart old-age care," "old-age service," "Internet old-age care," "aging," and other related terms (2). To ensure the accuracy of text analysis, the process of text analysis was compared by members of the author's team, and a unified conclusion was reached after a group discussion on any divergent parts. To ensure the accuracy of the selected older adult care policy samples, the members of the research group screened the pension-related policies separately. After the preliminary screening, they sorted out and confirmed the 2011–2019 policies through group discussion. The policies promulgated in the past few years to promote the development of China's old-age security and its strong correlation.

3.2. Variable measures and model selection

3.2.1. Variable measures

3.2.1.1. Dependent variable

Number of senior centers (*SC*): a senior center is a public place dedicated to providing leisure, entertainment, and communication, and to cultivating the mood of the older adult. It is a special type of public building. Based on the pension model of home care and community action, it aims to meet the leisure and older adult care needs of older people. The data on the number of older adult activity stations/centers/rooms in this article are derived from the China Stock Market & Accounting Research Database (CSMAR), the most recognized database in China.

3.2.1.2. Argument

Based on the research of Rothwell and Zegveld (30), this paper focuses on the policy goal dimension of older adult care policy and subdivides policy tools into three categories based on the classification standards of the existing literature, namely demand, supply, and environment. Among them, the policy strength is divided into the following five categories: (1) Notices, announcements; (2) Provisional regulations, measures, opinions, and plans of various ministries and commissions; (3) Interim regulations and plans issued by the State Council and regulations of various ministries and commissions; (4) Regulations promulgated by the State Council and decrees issued by various ministries and commissions; (5) Laws promulgated by the National People's Congress and its Standing Committee. Based on the quantitative analysis of older adult care policies, this paper measures the comprehensiveness, consistency, and balance of different policy types in the same dimension and different policy indicator combinations in the same policy type of the government's old-age security policies promulgated from 2011 to 2019. When calculating the eigenvalues of the combination of science and technology policy objectives and policy tools, the average value of the sum of the indicators under the policy objective or tool dimension was used to represent its eigenvalue score.

The formula for calculating the policy mix is as follows:

$$TS_t = \sum_{j=1}^{N} \text{Score}_{tj} \times P_{tj} \quad t \in [2017, 2019] \quad (1)$$

$$POL = \sum_{r=1}^{l} TS_t^r \quad (2)$$

In the above formula, t refers to the year, j represents any science and technology policy promulgated in year t, N is the sum of science and technology policies promulgated in year t, and Score measures the index score of the policy. P reflects the effectiveness of the policy, and TST represents the indicator characteristics of the science and technology policy promulgated by the government in year t. r represents policy indicators, and l is the total number of policy indicators within the same policy type.

When measuring the consistency of the science and technology policy mix, the policy indicator vector is constructed based on the policy indicators. The cosine value of the average vector angle is measured by analyzing the policy text. The consistency of the policy mix is measured, and the calculation $X_t^i = \left(x_t^{i1}, x_t^{i2}, \ldots, x_t^{il} \right)$ formula is as follows:

$$POL = \left(\sum_{r=1}^{l} TS \right) \times \frac{\sum_{i=1}^{k} \sum_{j=1}^{k} \cos\left(X_t^i, X_t^j \right)}{N \times (N-1)/2} \quad (3)$$

$$\cos\left(X_t^i, X_t^j \right) = \frac{\sum_{r=1}^{l} \left(x_t^{ir} \times x_t^{jr} \right)}{\sqrt{\sum_{r=1}^{l} \left(x_t^{ir} \right)^2} * \sqrt{\sum_{r=1}^{l} \left(x_t^{jr} \right)^2}}, \forall i \neq j \quad (4)$$

In the above formula, i, j refers to any two science and technology policies issued by the government in year t, which represents the vector angle cosine value between policy i and $\cos\left(x_t^i, x_t^j \right)$ j. The value reflects the consistency between policies.

When measuring the balance of the science and technology policy mix, the correlation index between the policy indicators is first measured, and then the balance of the policy mix is measured by calculating the standard deviation of the correlation index. The calculation formula is as follows:

$$Pol_t^d = \left[\frac{|TS_{mt} - TS_{nt}|}{\sqrt{TS_{mt} + TS_{nt}}} \right]^{-1}, \forall m \neq n \quad (5)$$

$$TolPol_t = \sqrt{\frac{\sum_{d=1}^{n^*} \left(Pol_t^d - \frac{\sum_{d=1}^{n^*} Pol_t^d}{n^*} \right)^{-1}}{n^*}} \quad (6)$$

In the above formula, m and n represent different policy indicators, and d refers to the combination of policy indicators. n^* indicates the sum of two combinations of science and technology policy indicators.

3.2.1.3. Control variables

This paper controls for factors that may affect the number of senior centers and introduces the following control variables: (1) Pension income (abbreviated as *PI*). This reflects the pension level of each region. The higher the pension income, the stronger the ability to build senior centers, (2) Pension outlays *(PO)*, reflecting the level of fund expenditure in each region in terms of pension security. The higher the value, the more attention the region attaches to the guarantee of pension services, (3) GDP *per capita* (*PG*) GDP *per capita* reflects socioeconomic development. The higher its value, the more resources will be available to invest in the number of centers for the older adult, (4) Fixed assets investment (*FI*), reflecting the strength of resources invested in social construction in various regions of China. The more fixed asset investment is made, the more resources can be used to build senior centers, (5) Old-age dependency ratio (OR). The higher the proportion of older adult support, the higher the demand for senior centers, and the greater the possibility of society investing resources in senior centers, thia variable is derived from CSMAR, and (6) Education level (*EL*). Measured by the proportion of general college graduates to the total population, the higher the level of social education, the more requirements for the physical and mental health of the older adult, and the higher the possibility of investing in the construction of senior centers.

3.3. Model selection

In order to solve the potential endogeneity, we employed a two-step system GMM regression method to investigate the effect of the older adult care policy mix on the construction of senior centers (31, 32). This method can handle endogenous regressors and is specifically suitable for the use of predetermined but not strictly exogenous regressors (33). The two-step system GMM can better solve weak instrument problems (32) and handle endogenous regressors. It is beneficial to the use of predetermined but not strictly exogenous regressors (33). The full model was established using the following equation:

$$SC_{it} = \beta_1 \, EPM_{it} + \beta_2 \, EPM_{it}-1 + \beta_3 \, PI_{it} + \beta_4 \, PO_{it} + \beta_3 \, PG_{it} + \beta_3 \, FI_{it} + \beta_3 \, OR_{it} + \beta_3 \, EL_{it} + \varepsilon_{it}$$

3.4. Results

Table 2 shows the means, standard deviations, and bivariate correlations of the variables. The correlation coefficient is a statistical indicator originally designed by Karl Pearson, which measures the degree of linear correlation between variables (34). To determine whether there were potential multicollinearity issues, variance inflation factors (VIF) of variables in the model were tested. All the VIFs were far lower than 10, which suggest that multicollinearity was not a significant issue (35).

TABLE 2 Means, standard deviations, and bivariate correlations of variables.

	Variables	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9
1	SC	10884.53	11728.71	1.000								
2	Comprehensiveness	114.6667	73.95074	−0.084	1.000							
3	Balance	1.218002	0.3333793	−0.044	−0.421***	1.000						
4	Consistency	41.864	27.70725	−0.087	0.992***	−0.377***	1.000					
5	PI	1060.934	876.1212	0.357***	0.301***	−0.069	0.299***	1.000				
6	PO	923.1701	750.1287	0.334***	0.368***	−0.087	0.366***	0.953***	1.000			
7	FI	17056.03	12625.88	0.612***	0.234***	−0.128**	0.225***	0.671***	0.671***	1.000		
8	PG	54021.61	26225.68	0.020	0.263***	−0.078	0.261***	0.603***	0.557***	0.255***	1.000	
9	EL	0.2641542	0.1016133	−0.172***	0.180***	−0.107*	0.172***	0.286***	0.307***	0.034	0.649***	1.000
10	OR	13.8324	3.408956	0.218***	0.367***	−0.091	0.366***	0.564***	0.681***	0.544***	0.305***	0.319***

$n = 2,884$ for mean and standard deviation. Correlations ≥ 0.06 are significant at the 0.001 level. t statistics in parentheses, *$p<0.05$, **$p<0.01$, ***$p<0.001$.

3.4.1. The impact of different policy tool combinations on the supply of older adult care service resources

This section analyzes the impact of the comprehensiveness, consistency, and balance of older adult care policy tools on the construction of senior centers. Table 2 presents the regression results predicting the effects of the older people policy mix on the establishments for senior centers. Model 1 suggests that the comprehensive older adult care policy mix tool will positively promote the construction of senior centers ($\beta = 0\ 22$, $p < 0.01$). This paper verifies the hypothesis 1 proposed in this paper, indicating that the increase in the breadth of the government's pension-related policy mix and the strengthening of synergy between policies will promote the construction of older adult care centers.

Based on the results in Model 2, unlike our hypothesis 2, it appears that the balance of older adult care policy mix tools negatively inhibits the construction of senior centers ($\beta = -3043.60$, $p < 0.01$). This shows that the more balanced the development of the indicators of supply policy, demand policy, and environmental policy in the older adult care policy tools, the more detrimental it will be to the construction of senior centers.

Model 3 presents the effects of the older adult care policy mix tool consistency promoting the construction of senior centers ($\beta = 20.44$, $p < 0.01$). This verifies the hypothesis 3 put forward in this paper and proves that when the degree of similarity between the older adult care policies proposed by the government increases, it will help the resource input of the construction of the older adult care activity center.

Based on the results, the residuals of all models were significantly first-order autocorrelational at the 5% level. There was no second-order autocorrelation, and none of the Sargan statistics were significant. This shows that the instrumental variables used in each model are valid (Table 3).

3.4.2. The impact of policy mix within the same policy instrument on the construction of senior centers

In this paper, the older adult care policy tools are divided into three types: demand policy, supply policy, and environmental policy. The impact of the comprehensiveness, consistency, and balance of these three policy tools on the construction of senior centers is analyzed, and Table 4 shows the results.

The data analysis results in Table 4 show that from the perspective of the policy tools, as proposed above, the synthesis of demand policy, supply policy, and environmental policy can positively promote the construction of senior centers, indicating that the higher the level of policy promulgation departments in each sub-dimension of policy tools and the wider the scope of policy formulation, the more significant the promotion effect on the construction of senior centers. Second, the balance of demand policy, supply policy, and environmental policy has a negative impact on the construction of senior centers, indicating that the more balanced the setting of the internal indicators of each policy tool, the more even the development of the older adult service system. Finally, the consistency of demand policy, supply policy, and environmental policy will promote the construction of senior centers, because the consistency between policies will enhance the confidence of social resources in investing in older adult care centers. It will be more conducive to the construction

TABLE 3 The effects of older adult policy mix on senior centers.

SC	Model 1	Model 2	Model 3
L.SC	0.22*** (37.58)	0.19*** (38.22)	0.22*** (35.98)
Comprehensiveness	7.51*** (16.40)		
Balance		−3043.60*** (−54.57)	
Consistency			20.44*** (16.61)
PI	0.21 (0.70)	0.16 (0.79)	0.55** (2.60)
PO	0.26 (0.65)	0.89** (3.29)	−0.25 (−1.00)
FI	0.13*** (13.59)	0.01 (0.87)	0.14*** (13.02)
PG	−0.10*** (−13.60)	−0.07*** (−12.62)	−0.11*** (−14.15)
EL	18045.05*** (26.77)	10876.84*** (10.79)	19617.04*** (18.47)
OR	−1352.81*** (−43.99)	−1178.39*** (−26.81)	−1355.95*** (−43.67)
Constant	22039.97*** (22.01)	26434.36*** (24.01)	22366.47*** (23.50)
Sargan	22.90	26.06	25.35
sarganp	(0.69)	(0.52)	(0.55)
arm1	−1.56	−1.87	−1.53
ar1p	(0.12)	(0.06)	(0.13)
arm2	1.56	1.54	1.59
ar2p	(1.88)	(1.88)	(1.89)
N	216	216	216

t statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

and operation of older adult care institutions, thereby helping to promote the investment of pension resources in the building of senior centers.

4. Conclusions and countermeasures

4.1. Conclusion

This paper quantitatively analyzed the policy documents related to old-age security issued by the State Council and various ministries and commissions from 2011 to 2019, exploring the impact of the characteristics of the old-age policy mix on the senior centers in various regions of China by establishing an empirical analysis model. The main conclusion of this study is that in order to promote the development of the pension security industry, the comprehensiveness and consistency of the older adult care policy mix tools issued by the government will significantly promote the construction of senior centers, and the balance of older adult care policy mixes will inhibit the resource input of older adult care activity center construction. When exploring the impact of different policy indicator combinations on the construction of senior centers in policy tools, the three policy types under policy tools, demand policy, supply policy, and environmental policy, comprehensiveness, consistency, and balance, will have an impact on the construction of the senior center. Among them, the comprehensiveness and consistency of the combination of demand policy, supply policy, and environmental policy will have a positive impact on the construction of senior centers, and the balance will significantly inhibit the resource construction of senior centers. We believe that the balance of the older adult care policy mix will have a negative impact on the

construction of senior centers because unlike the needs for eating, drinking, and medical treatment to meet the basic living security of the older adult, the purpose of the construction of senior centers is to promote the physical and mental health of the older adult at the same time, and promote the healthy development of the older adult (27). If the older adult care policy is too balanced and there is no special attention paid to the construction of senior centers, then under normal circumstances, the pension resources will be more inclined to meet the basic needs of the older adult in terms of eating, drinking, and medical treatment. Therefore, the balance of policy mix is not conducive to the construction of senior centers.

4.2. Policy implications and recommendations

The increasing proportion of the population aged 65 or over has raised growing challenges to long-sustainable development of public finances across countries (4, 36). In recent years, the role of senior centers in promoting the physical and mental health of the older adult has become increasingly important. The construction of senior centers is not only affected by the market environment but also plays a very important role in the national political system and macro situation (37). The relevant policies issued by the central government and governments at all levels are important promoters encouraging various bodies in society to actively build senior centers under the premise of limited economic benefits. As one of the important macro-level factors promoting the smooth development of old-age security, the influence of the characteristics of old-age policy mixes on the construction of old-age activity centers was explored and was found to be of great significance.

TABLE 4 The impact of the older adult care policy mixes on the construction of senior centers.

SC	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
L. SC	0.22*** (37.58)	0.19*** (38.22)	0.22*** (35.98)	0.21*** (40.16)	0.18*** (48.20)	0.19*** (39.42)	0.22*** (38.32)	0.20*** (26.43)	0.21*** (42.62)
Comprehensiveness	7.51*** (16.40)			53.44*** (41.05)			23.69*** (25.62)		
Balance		−3043.60*** (−54.57)			−731.43*** (−59.73)			−498.53*** (−9.15)	
Consistency			20.44*** (16.61)			64.99*** (51.74)			48.61*** (20.03)
PI	0.21 (0.70)	0.16 (0.79)	0.55** (2.60)	0.98*** (3.77)	0.47** (3.20)	0.44 (1.48)	0.72* (2.27)	−0.03 (−0.11)	0.47 (1.42)
PO	0.26 (0.65)	0.89** (3.29)	−0.25 (−1.00)	−0.52 (−1.61)	1.11*** (3.56)	0.02 (0.04)	−0.25 (−0.58)	0.72* (2.13)	−0.18 (−0.38)
FI	0.13*** (13.59)	0.01 (0.87)	0.14*** (13.02)	0.12*** (11.15)	0.03*** (3.70)	0.10*** (13.61)	0.13*** (11.64)	0.10*** (5.40)	0.14*** (12.68)
PG	−0.10*** (−13.60)	−0.07*** (−12.62)	−0.11*** (−14.15)	−0.10*** (−23.97)	−0.04*** (−5.53)	−0.09*** (−18.90)	−0.11*** (−22.35)	−0.10*** (−21.94)	−0.11*** (−24.69)
EL	18045.05*** (26.77)	10876.84*** (10.79)	19617.04*** (18.47)	14956.65*** (26.77)	10660.80** (2.81)	13687.97*** (19.62)	17214.56*** (16.65)	17427.48*** (11.70)	18079.32*** (18.05)
OR	−1352.81*** (−43.99)	−1178.39*** (−26.81)	−1355.95*** (−43.67)	−1350.06*** (−47.27)	−1157.07*** (−25.28)	−1325.20*** (−68.47)	−1335.35*** (−53.17)	−1252.89*** (−36.47)	−1334.84*** (−60.08)
Constant	22039.97*** (22.01)	26434.36*** (24.01)	22366.47*** (23.50)	23415.25*** (23.73)	23389.32*** (15.55)	22474.26*** (21.11)	22329.24*** (23.19)	23661.03*** (24.21)	22335.15*** (23.23)
Sargan	22.90	26.06	25.35	25.33	27.23	21.52	24.36	26.09	23.84
sarganp	(0.69)	(0.52)	(0.55)	(0.56)	(0.45)	(0.76)	(0.61)	(0.51)	(0.64)
arm1	−1.56	−1.87	−1.53	−1.58	−1.83	−1.65	−1.56	−1.66	−1.56
ar1p	(0.12)	(0.06)	(0.13)	(0.11)	(0.07)	(0.10)	(0.12)	(0.10)	(0.12)
arm2	1.56	1.54	1.59	1.48	1.56	1.51	1.54	1.60	1.59
ar2p	(1.88)	(1.88)	(1.89)	(1.86)	(1.88)	(1.87)	(1.88)	(1.89)	(1.89)
N	216	216	216	216	216	216	216	216	216

p values in parentheses. Significant at 1%, ** at 5%, * at 10%. The level is significant. *t* statistics in parentheses, *$p<0.05$, **$p<0.01$, ***$p<0.001$.

First, according to the above research conclusions, the formulation of older adult care policies needs to be considered as a whole, rather than just considering the formulation of a single policy, because there is an interaction between every single policy, and there are differences in the impact of the comprehensive, consistent, and balanced combination of older adult care policies on the construction of senior centers.

Second, strengthening the social security of the older adult group should not only involve the physical health of the older adult, but should also include the clothing, food, housing, and transportation needs of the older adult. It is also necessary to pay attention to the mental health and cultural needs of the older adult, to provide home care services for the older adult with chronic diseases under the guidance and support of the government, and to offer convenient services for the older adult who are physically weak. Service providers should have the ability to provide medical nursing, psychological counseling, and other professional services for the older adult to promote their physical and mental health and ensure the construction of high-quality older adult care services for the older adult.

Third, the government should play a leading role in promoting the supply of older adult care services. It should also be noted that in addition to the government, a variety of other bodies, such as families, communities, and enterprises, have their part to play. In order to ultimately achieve the physical and mental health of the older adult, a variety of subjects should be called upon to invest in the supply of older adult care resources, and as a community with unique natural advantages in older adult care services, the government should focus on building a unified older adult care service system (38), helping older people achieve physical and mental health by promoting the number of activity centers for the older adult.

Fourth, the government may implement older adult care service policies based on regional environment and preferences for older adult care needs, and try to avoid one-size fits all older adult care service policies. Our government can improve the allocation of older adult care service resources and increase the utilization rate of older adult care service resources by taking suitable policy tools. In order to promote the comprehensive development of older adult care services and broaden the older adult care service market, the government can take measures as expanding the promotion of older adult care service policies, clarifying older adult care service standards, improving older adult care service information platforms and innovating older adult care service products.

Finally, the key to improving older adult care quality is to innovate, the government should pay more attention on innovation. Innovation in older adult care area can help integrate resources, and provide integrated maintenance services. This not only meets the needs of healthy older adult care, but also is a common trend in the supply reform and policy innovation of older adult care services in countries. Policy innovation is needed to support, guide, and supervise the reform of medical and older adult care integration, including cross departmental collaboration strategies, exploratory long-term care insurance coverage policies, and human resource reserve policies.

4.3. Limitations and future research

Our study has several limitations, which offer possibilities for future studies. First, this paper only investigates the impact of old-age related policy mixes on the construction of senior centers. There are many aspects not covered in this article that are closely related to promoting the physical and mental health of the older adult and the high-quality development of older adult care services. These aspects include the construction of pension systems, the provision of basic security for the older adult, and the standardization of nursing homes. Future studies could investigate these topics.

Second, this paper only discusses emerging economies such as China. The universality of the research conclusion remains to be verified. Future studies could apply this study to developed countries like the United States, France, and Japan.

Moreover, this study does not explore the influence mechanism of the characteristics of provincial and ministerial governments or policy mixes at different regional levels on the construction of senior centers. Future research could further clarify the impact of provincial and ministerial policy mix characteristics on the construction of older adult activity stations.

Finally, there is no consistent conclusion on the impact of comprehensiveness, consistency, and balance of the policy mix related to older adult care services on innovation. Future research could expand and supplement the results of quantitative analysis by combining case studies, thereby enhancing the credibility of research conclusions through mixed research methods. Future research could use questionnaire research to explore the impact of old-age-related policies on the construction of senior centers.

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

XC: conceptualization, methodology, and validation. The author have read and agreed to the published version of the manuscript.

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.

Publisher's note

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Geriatric depression: prevalence and its associated factors in rural Odisha

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The world's population is aging rapidly, and the epidemiological transition has led to increased mental disorders worldwide. Geriatric depression is masked by multiple comorbidities or the natural process of aging. Our study aims to estimate the prevalence of geriatric depression and find the risk factors associated with geriatric depression in rural Odisha. The study was a multistage cross-sectional study conducted in the Tangi block, district Khordha, Odisha, from August 2020 to September 2022, among 520 participants selected by probability proportional to size sampling. From the selected participants, eligible 479 older adults were interviewed using a semi-structured interview schedule, Hindi Mini Mental Scale, Geriatric Depression Scale-15, and Hamilton Depression Rating Scale. The step forward multivariable logistic regression was used to assess the associated factors of depression among older adults. Among our participants, 44.4% (213) of older adults were depressed. Substance abuse in family members [AOR: 16.7 (9.1−30.9)], history of elder abuse [AOR: 3.7 (2.1−6.7)], physical dependency [AOR: 2.2 (1.3−3.6)], and financial dependency [AOR: 2.2 (1.3−3.6)] are significant independent risk factors associated with geriatric depression. Living with children [AOR: 0.33 (0.18−0.59)] and recreational activity [AOR: 0.54 (0.34−0.85)] are significant protective factors of geriatric depression. Our study found that geriatric depression is highly prevalent in rural Odisha. Poor quality of family life and physical and financial dependency was found to be the most significant risk factor for geriatric depression.

KEYWORDS

geriatric, depression, prevalence, rural Odisha, elderly, cross-sectional study

Introduction

The world's population has been rapidly aging for the last 50 years. The National Policy on Older Adults defines "senior citizen" or "geriatric population" as 60 years and above (1). The global geriatric population has doubled from 1990 to 2019 by 703 million (2) United Nations (UN) world geriatric population prospects estimate the global aging population to double again by 2050 and is projected to reach nearly 1.5 billion. Western Asia, including India, expects an increase in the geriatric population of ∼230% (2). Being prepared to address the needs of the growing older adult population is a necessity. According to the WHO, the prevalence of geriatric depressive disorders varies from 10 to 20% in different regions (3, 4). A meta-analysis on the prevalence of depression among older adults (60 years and above) in India from 1997 to 2016 revealed that 34% of older adults in India suffer from various depressive disorders (5).

Depression is a common and severe disorder affecting our feelings and daily activities (6). The individual usually suffers from depressed mood, loss of interest, and reduced energy leading to increased fatiguability and diminished activity (7). Depressed older adults are less likely to endorse their symptoms, and they often attach them to existing physical illnesses (8). Addressing the growing burden of depressive disorders in the older adults of India is possible by increasing awareness about depressive disorders in older adults, timely diagnosis, and treatment. According to the WHO, the treatment gap (the number of people with a disease who are not in treatment) for mental illness in developing countries is as high as 75–85% (9). India's recent National Mental Health Survey (NMHS) revealed an 85% treatment gap for depressive disorders in India (10). Older adults are vulnerable to immobility and dependency, facing even more difficulty getting diagnosed and treated. Considering the facts from the metanalysis of the prevalence of geriatric depression, which states that 34% of older adults suffer from depression and that there is an 85% treatment gap for depression according to the National Mental Health Survey, we expect a vast number of undiagnosed older adults with depressive disorders (5, 10). The prevalence of depression varies in different regions and age groups (5). The risk factors in older adults also vary due to gender, sociocultural practices, and geographical areas (11). Apart from this, limitations in daily activities and social alienation can also be understood as major risk factors for depression in older adults (8, 12). Consequently, we hypothesized that some specific risk factors of older adults residing in rural areas could increase the risk of depression. Therefore, our study aims to assess the prevalence of depression to understand the burden of depressive disorders among older adults in rural Odisha and explore the risk factors of depression among them.

Materials and methods

Our study was a community-based cross-sectional study in Tangi Block in Khordha district in Odisha State in Eastern India. The block has a total of 6 sectors and 154 villages. The field practice area of AIIMS Bhubaneswar under Tangi RHTC consists of six sectors.

The study population was older adults aged 60 years and above residing in TANGI BLOCK, District Khordha, during the data collection period from August 2020 to September 2022. The COVID-19 pandemic affected the study period due to the lockdowns and restrictions. Assuming a prevalence of 37.9%, a relative error of 15%, and a confidence level of 95%, the sample size was 296. Furthermore, taking a design effect of 1.5, the sample size needed was 444. After considering the exclusion as 5% and the non-response rate as 10%, the final sample estimated was 519 persons aged 60 years and above. Our sampling strategy was probability proportional to the size sampling of 20 villages. The sample per village was rounded off to 26 after dividing the sample size 519 among 20 villages (25.9 and a total sample size of 520 participants were interviewed (Figure 1). All persons aged 60 years and above residing in this area for at least the last 6 months were included in the study. Older adults with impaired cognition (assessed by Hindi Mental State Examination) and those who were unable to respond because they had hearing loss, were unable to speak, had no

comprehension, or were too sick to respond were excluded, as the GDS-15 Questionnaire could not be applied to those participants. Our sampling strategy involved multistage sampling, as explained in Figure 2.

Data collection and statistical analysis

Data were collected using one-to-one interviews at the participant's house after ensuring privacy. A single investigator who was trained in the psychiatry department of AIIMS Bhubaneswar conducted the interviews. Depression was screened using the Geriatric Depression Scale 15 (GDS-15)—Odia after ruling out older adults with impaired cognition using the Hindi Mental State Examination (HMSE). The GDS-15-Hindi was translated into Odia and validated (linguistic, face, and content validity) among older adults from a similar study area. A cut-off of 8 was taken for screening for depression as per GDS-15 in Indian settings (13, 14). The depression of participants screened positive by GDS-15 was quantified by the Hamilton depression rating scale—17 (HDRS-17). Sociodemographics and other factors associated with depression were assessed using a semi-structured questionnaire. The data were entered into Epicollect5 after data validation. The datasheet was cleaned for missing and inappropriate variables, and the final variables were coded in Microsoft Excel 365 for analysis. Statistical analysis was done using SPSS 28. Categorical variables were summarized by percentages. A logistic regression analysis was used to assess possible risk factors. All variables with univariable association <0.25 and universal confounders such as age, gender, and education were included in the step forward multivariable logistic regression model with a probability of entry and removal of 0.05 and 0.10, respectively, to identify independent risk factors.

The risk factors were calculated as odd ratios (OR) with 95% confidence intervals (CI). The significance of differences was defined as a two-tailed p-value of < 0.05.

Results

Among the sample of 520 older adults identified by our study, 497 were found to be eligible for the study. Out of the 497 participants, 21 did not give consent for participation. Thus, the non-response rate was only 3.6% for our research, and coverage of 96.4% (479) was achieved. Gender was almost equally distributed among our participants, with 55.8% (267) women and 44.2% (212) men, and 73% (350) of the participants were in the younger age group (60–74 years old). In comparison, only 7% (15) of the participants were in the older age group (> 85 years). Older adults residing in joint or three-generational families constituted 59.5% (285), and older adults living with their spouses constituted 66.2% (194). Most of them were also illiterate (41.9%, 201), unemployed (52.4%, 251), and had lower socioeconomic status (53.2%). It was also observed that 48.5% of our participants had medical insurance (Table 1).

The proportion of studied older adults who screened positive for depression was 44.4% (213) (Table 2). Most of them, 74% (158), had mild depression, while 15% (16) had moderate depression and 2% (4) had severe depression (Table 3). According to our screening,
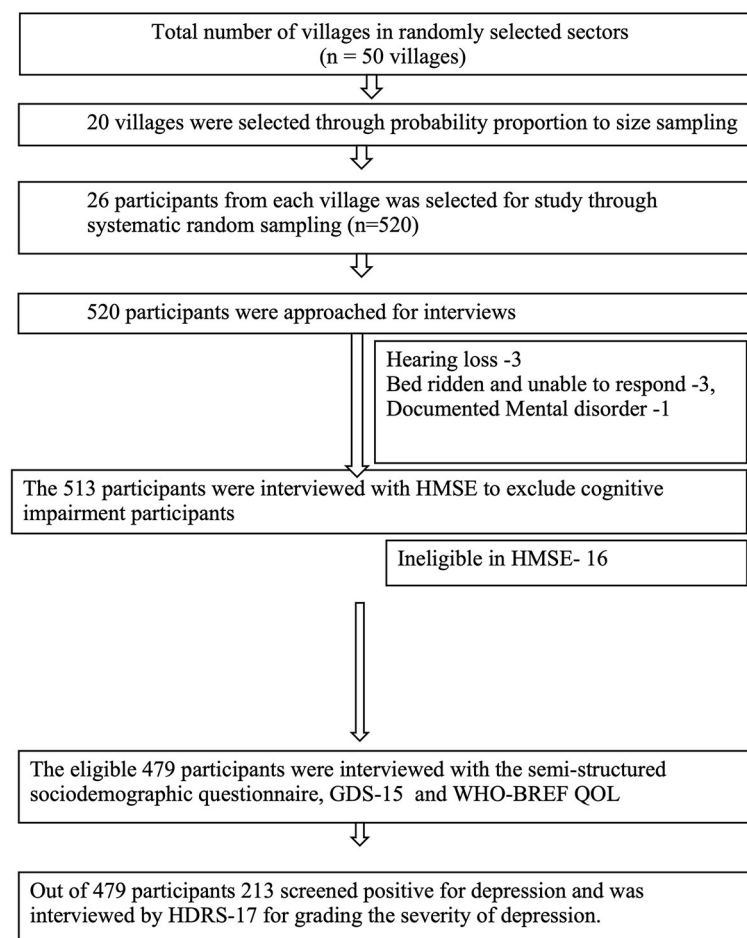
FIGURE 1
Study flow chart.

58% (124) of older adult men were found to be depressed compared to 33% (89) of older adult women. The prevalence of depression was highest in the middle age group (75–84 years = 50%, 48) than in both the younger (150, 42.8%) and older age group (15, 44.11%).

The prevalence of depression among participants living without a spouse was 77.7% (126) and among participants from nuclear families was 50% (97). Older adults residing with their children had a prevalence of only 40% (156) compared to 64% (57) among older adults living without their children. Prevalence of depression was higher in participants with adverse events in the family (129, 49.4%), substance use among family members (96, 65.7%), and elder abuse (68, 72.3%).

Prevalence of depression was lower in the older adults with physical activity (108, 39.8%), recreational activity (91, 35.5%), and social participation (63, 39.8%), and was higher in those who were physically dependent on others for self-care (6, 75%) and financially dependent older adults (173, 64.07%). There was no difference in the prevalence of depression among older adults with current comorbidities (182, 44.8%) and without comorbidities (31, 42.4%). Similarly, the prevalence of depression in older adults with non-communicable chronic diseases was 45.08% [179 and in those without non-communicable chronic diseases, it was 41.4% (15)].

Step forward multivariable logistic regression was applied, considering depression as the dependent variable and sociodemographic and other factors as the independent variable. The model was statistically significant, with 46.9% of the variability in depression among the older adults explained [R^2 (Nagelkerke): 0.469].

We found that substance abuse in family members [AOR: 16.7 (9.1–30.9)], history of elder abuse [AOR: 3.7 (2.1–6.7)], physical dependency for self-care [AOR: 2.2 (1.3–3.6)], and financial dependency [AOR: 2.2 (1.3–3.6)] were significant independent risk factors associated with depression among older adults. Living with children [AOR: 0.33 (0.18–0.59)] and recreational activity [AOR: 0.54 (0.34–0.85)] were found to be significant protective factors against depression in older adults (Table 4).

Discussion

In the latest census of India, older adult men outnumbered older adult women in Odisha, but the distribution was similar to our study population in the younger age group (women: 51%, men: 49%) (17). The study participants were 55.8% women and 44.2% men, and the majority were in the younger age group

FIGURE 2
Sampling strategy.
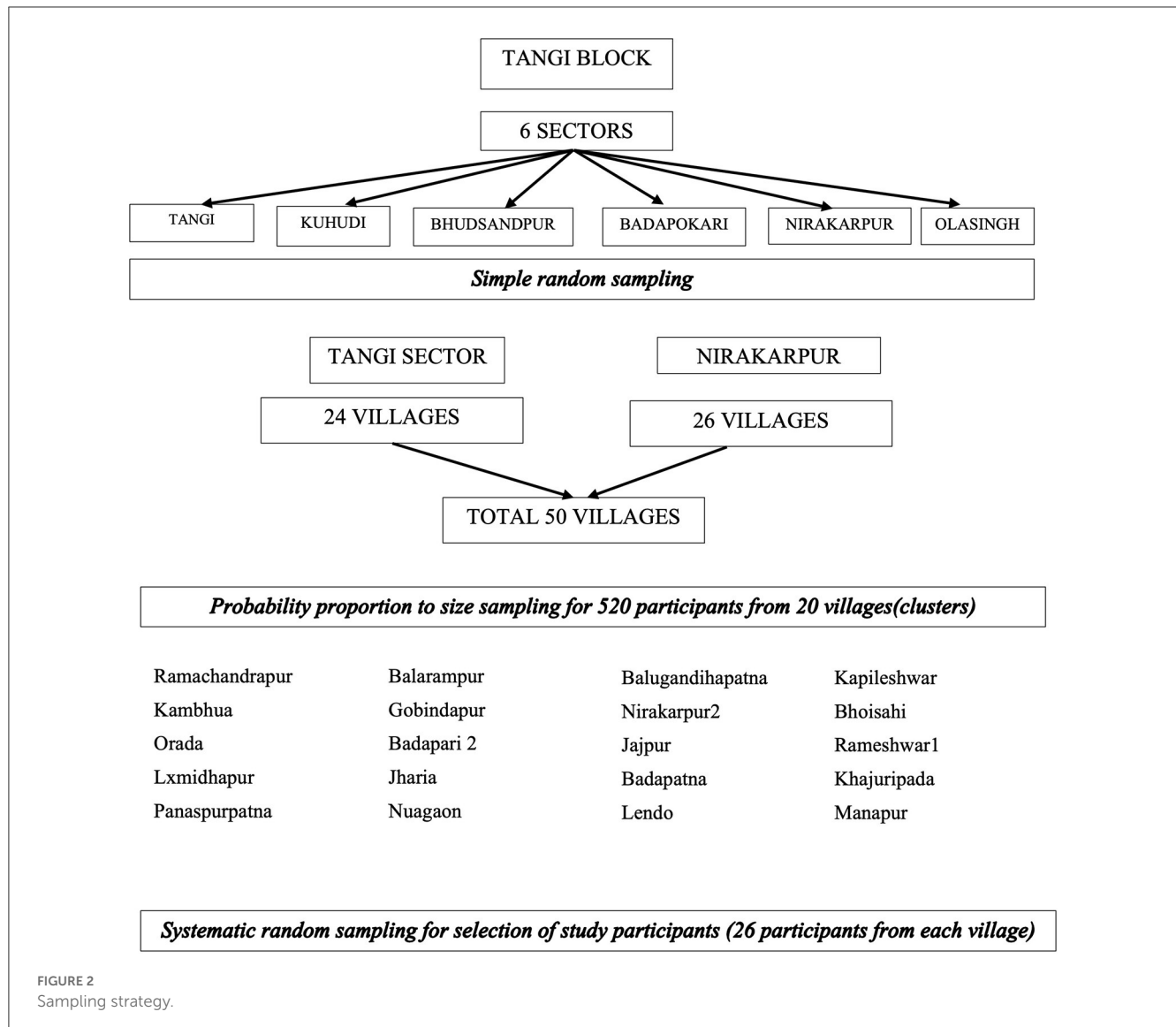
(75%). Our study identified the prevalence of depression among older adults residing in rural Odisha as 44.4% after screening using GDS-15. Further grading with HDRS showed that among the depressed, 74.2% of the participants had mild depression and 1.9% had severe depression. Pilani et al. (5) conducted a meta-analysis to study the prevalence of depression among older adults in India from 1997 to 2016. The pooled prevalence of depression from 56 studies was 34.4% (29.3–39.6); however, a subgroup analysis from 28 studies in rural areas showed a prevalence similar to our study, 37.8% (29.9–45.9). In the same study by Pilani et al., a subgroup analysis from six studies in Eastern India showed a significantly higher prevalence of depression among older adults [47.9% (30.1–66.1), P-value: 0.0075] (5). The difference may be due to regional and geographic differences, including cultural background, social participation level, and healthcare access (18, 19). A study by Ashe et al. in the urban areas of Odisha also found a prevalence of depression of 44.2% (20). In our literature search, we could not find any studies to quantify depression among the rural older adults of Odisha. Thus, our investigation will be one of the first studies to assess the depression status of older adults in rural Odisha.

The prevalence of depression varies according to the scale used. A subgroup analysis of studies that used the GDS scale in the metanalysis by Pilani et al. (5) showed a pooled prevalence of 37.9% (31.5–44.5) (5). Another meta-analysis by Brooke Levis et al. found that screening tools such as GDS have a higher pooled prevalence (31%) than diagnostic tools (17%) (21). We also used HDRS to grade the severity and validate the diagnosis of depression in older adults screened positive by the GDS. The studies that used HDRS have shown a lower prevalence than our study. The survey among community-dwelling older adults in rural Haryana found the prevalence of depression to be 14.3% (22). A similar study in Himachal Pradesh found the prevalence of depression among older adults to be only 9.5% (23). A subgroup analysis of studies using HDRS in metanalysis by Pilania et al. (5) showed a pooled prevalence of depression among older adults of only 10.2% (5). The screening tools will have a higher prevalence than diagnostic tools. The difference is due to a higher sensitivity of

TABLE 1 Distribution of sociodemographic variables.

S. No.	Baseline characteristics	Category	Frequency	Percentage
1	Gender	Women	214	55.8
		Men	283	44.2
2	Religion	Hindu	462	96.4
		Muslim	17	3.6
3	Age	Younger age group (60 to 74 years)	352	73.1
		Middle age group (75 to 84years)	105	19.8
		Older age group (>/= 85 years)	40	7.1
4	Marital status	Married and living with spouse	162	66.2
		Unmarried/divorced/Separated	317	33.8
5	Type of family	Joint family and three generational family	285	59.5
		Nuclear family	194	40.5
6	Education	Illiterate	201	41.9
		Read only	82	17.3
		Read and write	41	8.5
		Primary	59	12.3
		Middle	48	10
		High and above	48	10
7	Employment	Unemployed	251	52.4
		Unskilled	112	23.4
		Semi-skilled	9	1.8
		Skilled	40	8.4
		Semi-professional	25	5.3
		Professional	42	8.7
8	Poverty line based on annual income	APL	395	83.5
		BPL	78	16.4
9	House status	No house	59	12.3
		Kucha	111	23.1
		Mixed	125	26.1
		Pucca	184	38.4
10	SES (according to Uday Pareek's scale)	Lower class	59	53.2
		Upper Lower	111	40.9
		Lower Middle	125	5.2
		Upper middle	184	0.7
11	Insurance	No	246	51.5
		Yes	233	48.5

screening tools (24). Positive screening by a screening tool should be confirmed by a psychiatrist for clinical diagnosis. However, screening followed by clinical diagnosis, treatment, and follow-up is the ideal management of depression in primary care settings (25).

In the present study, substance abuse among family members was the most vital associated factor [OR: 16.75 (9.082–30.926)] for depression among older adults residing in rural Odisha. A study

by Ariyasinghe et al. (26) on women with spouses with substance use disorders in the rural community of Sri Lanka identified a significantly high prevalence (33.33%; CI: 25.93–40.73%) of major depressive disorders (26). The effects of children's substance use on parents are significantly less studied. Our literature search could not find any studies assessing the impact of children's substance use on older adults. This area should be studied more in the future to

understand how the substance use of family members affects the mental health of older adults.

The present study could not find any significant association between depression and comorbidities, while physical dependency for self-care 12.9 (2.9–56.2) was significantly associated with depression. Even though several studies have found a significant association of depression with the morbidity status of older adults, our study suggests that morbidities without activity restriction and physical dependency are not risk factors for depression (27–32). In the book Physical Illness and Depression in Older Adults, Shaffer et al. (16) also studies that activity restriction can lead to depression in older adults (16). Schaffner explains that late-life changes like activity restriction following a physical illness can influence depression through the psychosocial pathway, which focuses on losing independence and control over one's life (33). A study among cancer patients found that activity restriction explained the significant additional variance in depression beyond the illness severity (34). A study by Lee et al. (15) found that after adjusting for general health and the severity of the morbidity, higher activity restriction was associated with higher depression. A cross-sectional study from rural Tamil Nadu also showed that being physically dependent (O*R* = 1.01; CI = 0.88–1.15) significantly affected depression among older adults (15). A study conducted in Sweden revealed that there was no discernible distinction in terms of illness or medication between older adults in primary care who were depressed and those who were not. However, it was noted that depressed older adults exhibited a significant correlation with the restriction of activities. Still, limiting activities had a significant association with depressed older adults (35). Further studies focusing on the activity restriction aspect of morbidities should be explored to associate the causation.

As per the psychosocial model of physical illness and the learned helplessness theory, losing control over one's life has a permanent casual attribute to to depressive disorders in older adults. The present study also found another related variable, i.e., financial dependency, as a risk factor for depression among older adults. A US study that followed up on the older adults for 4 years found that older adults who were economically disadvantaged had a risk of persistent depression (36). The exposure to financial instability plus an unstable and unsafe environment due to economic dependency increased the risk of depression in the older adults of the US study (36). The Financial Survey Status of Older People in India found that good financial quality ensured good health in older adults (37). Financial dependence also complicates the treatment of depression in older adults with low income (38). A study among older adults in rural Andhra Pradesh assessing economic dependency and its relation to depression found that 68% of the economically dependent were depressed (39). The study from Jaipur also saw that 48.3% of the financially dependent were significantly associated with depression (40). Economic dependency further reduces control over one's life, leading to depression in older adults.

In the present study, recreational activity was a significant protective factor [OR: 0.542 (0.342–0.859)]. In a 14-year follow-up study of community-dwelling older adults, recreational activity attenuated the association between depression and multiple morbidities [adjusted relative risk = 0.99, 95% confidence interval (0.98, 0.99); p = 0.001] (41). A Brazilian study assessing different

TABLE 2 Prevalence of depression among older adults with GDS 15.

	Frequency	Percentage (CI)
Depressed	213	**44.4% (40.02–48.92)**
Non-depressed	266	55.6% (50.92–60.04)
Total	479	100%

TABLE 3 Severity scoring with HDRS.

HDRS	Frequency (N= 213)	Proportion (n=213)
No depression	20	9.38%
Mild	158	74.2%
Moderate	31	14.5%
Moderately severe	0	0
Severe	4	1.9%
Total	213	

domains of physical activity found that leisure and transport physical activity had a protective effect on depression. In contrast, physical work or household physical activity was a risk for depression in adults (42). Recreational activity assessed in our study included non-physical activities such as religious involvement, reading newspapers, listening to music, and watching TV. Physical activity was found to be significant in the univariate analysis [OR: 0.586 (0.234–0.938); *P*-value: 0.004] but was found to have no significance after multivariable analysis [0.897 (0.598- 1.196); *P*-value: 0.12]. This suggests that recreational activities without physical activity are more effective in the older adult population in reducing the risk of depression. However, our study was cross-sectional, and the temporality of the association could not be proved. The protective effects of recreational activities among older adults against depression should be explored further.

Older adult abuse is a neglected global health priority (43). A meta-analysis from 28 geographically diverse countries estimated a global pooled prevalence of 15·7% (95% CI 12.8–19.3) (44). The meta-analysis also found that psychological abuse was the most common, accounting for 11.2% of older adults (44). Older adult abuse is widely studied in developed countries. The close association between abuse and depression is also well-established. The most common abuse experienced by older adults is psychological and economic abuse, as evident from the meta-analysis from 28 countries (44). A bidirectional longitudinal Japan Gerontological Evaluation Study showed that people who experienced abuse had a 2.28 times higher risk of depression, and a follow-up after 3 years found those who were mildly to severely depressed before had a 2.23 times higher chance of experiencing abuse later on (45). Our study found elder abuse to be a significant risk factor for depression [AOR: 3.780 (2.113–6.760)]. A similar survey in Assam also found a positive correlation between abuse and depression (*r* = 0.619, *P* = 0.01) among older adults (46) A study from Nepal also found in a multivariable analysis that neglect (AO*R* = 2.995; CI: 1.249–7.181) and financial abuse (AO*R* = 4.728, CI: 1.836–12.173) contribute significantly to depression. Our study did not explicitly assess economic abuse, but financial dependency was significantly associated with geriatric depression.

TABLE 4 Logistic regression.

Variable	Number of participants (n= 479)	Depression present (n=213)	Odds Ratio	P- value	Adjusted Odds Ratio	P-value
Age (in years)						
Younger age group	350	150 (42.8%)	1.13 (0.56–1.7)	0.402		
Middle age group	95	48 (50%)	0.67 (0.22–0.89)	0.179		
Older age group	34	15 (44.11%)	Reference	Reference		
Gender						
Men	212	124 (58.4%)	1.02 (0.96–1.08)	0.09		
Women	267	89 (33.3%)	Reference	Reference		
Religion						
Hindu	462	207 (44.8%)	1.48 (0.78- 2.4)	1.2		
Muslim	17	6 (35.2%)	Reference			
Marital status						
Unmarried/divorced/separated	162	126 (77.7%)	Reference			
Married and living with spouse	317	87 (27.4%)	0.52 (0.48–0.57)	0.004		
Education						
Illiterate	201	97 (48.2%)	Reference			
Read only	82	40 (48.7%)	0.81 (0.33–1.94)	0.654		
Read and write	41	21 (51.2%)	0.44 (0.19–0.99)	0.049		
Primary	59	27 (45.7%)	0.35 (0.14–0.85)	0.021		
Middle	48	15 (31.2%)	0.39 (018–0.84).	0.017		
High school and above	48	13 (27.0%)	0.39 (0.19–0.79)	0.009		
Employment						
Unemployed	251	120 (47.8%)	Reference			
Unskilled	112	52 (46.4%)	0.94 (0.56–1.32)	0.75		
Semi-skilled	9	3 (33.3%)	0.54 (0.05–1.03)	0.27		
Skilled	40	12 (30%)	0.46 (0.36–0.56)	0.03		
Semi-professional	25	14 (56%)	1.38 (0.48–2.28)	0.34		
Professional	42	12 (28.5%)	0.43 (0.08–0.51)	0.02		
Type of Family						
Joint family (>5 members)	285	116 (40.7%)	Reference			
Nuclear (<5 members)	194	97 (50%)	1.47 (1.2–1.6)	0.04		
Poverty line (n= 473, 6 non-response)						
APL	395	163 (41.2%)	Reference			
BPL	78	45 (57.6%)	3.66 (2.8–4.4)	0.008		
House						
No house	59	33 (55.9%)	Reference			
Kucha	111	49 (44.1%)	0.50 (0.28–0.91)	0.39		
Mixed	125	59 (47.2%)	0.81 (0.5- 1.31)	0.15		
Pucca	184	72 (39.1%)	0.50 (0.45–1.13)	0.02		
SES (Uday Parik)						
0- lower class	255	129 (50.5%)	0.48 (0.44- 5.4)	0.56		

(Continued)

TABLE 4 (Continued)

Variable	Number of participants (n= 479)	Depression present (n=213)	Odds Ratio	P- value	Adjusted Odds Ratio	P-value
1- upper lower class	196	80 (40.8%)	0.73 (0.06–8.13)	0.78		
2- lower middle class	25	3 (12%)	3.66 (0.25–53.87)	0.37		
3- upper middle class	3	1 (33.3%)	Reference			
Insurance						
Yes	246	96	Reference			
No	233	117	0.78 (0.55- 1.12)	0.18		
Substance abuse among the participants						
No	366	117 (31.9%)	Reference			
Yes	113	96 (84.9%)	1.87 (0.9 – 2.4)	0.87		
Physical activity						
No	208	105 (50.4%)	Reference			
Yes	271	108 (39.8%)	0.58 (0.23–0.93)	0.004		
Recreational activity						
No	223	122 (54.7%)	Reference			
Yes	256	91 (35.5%)	0.47 (2.3–56)	0.001	0.542 (0.342- 0.859)	0.009
Social Participation						
Yes	158	63 (39.8%)	Reference			
No	321	150 (46.7%)	1.32 (0.89- 1.5)	0.15		
Substance use in family members (current)						
No	333	117 (35.1%)	Reference			
Yes	146	96 (65.7%)	15.1 (9.08–27.4)	<0.021	16.7 (9.1–30.9)	0.001
Financial Dependence						
No	209	80 (38.2%)	Reference		2.2 (1.3–3.6)	<0.001
Yes	270	173 (64.07%)	1.59 (1.08- 2.59)	0.01	Reference	-
Physical dependence for self-care						
No	471	207 (43.9%)	Reference			
Yes	8	6 (75%)	12.9 (2.9–56.2)	<0.001	6.8 (1.3–35.4)	0.001
Ever faced any elder abuse						
No	385	145 (37.6%)	Reference			
Yes	94	68 (72.3%)	4.32 (2.6 – 7.9)	0.001	3.7 (2.1- 6.7)	0.001
Living with their children/child						
No	89	57 (64.04%)	Reference			
Yes	390	156 (40%)	2.679 (1.6–4.3)	<0.001	0.33 (0.18–0.59)	0.023
Adverse events in family						
No	218	84 (38.5%)	Reference			
Yes	261	129 (49.4%)	1.77 (1.08- 2.2)	0.17	0.54 (0.34–0.85)	0.009
Comorbidities						
No	73	31 (42.4%)	Reference			

(Continued)

TABLE 4 (Continued)

Variable		Number of participants (n= 479)	Depression present (n=213)	Odds Ratio	P- value	Adjusted Odds Ratio	P-value
Yes		406	182 (44.8%)	1.01 (0.9- 1.4)	0.15		
Non-communicable disease							
No		82	34 (41.4%)	Reference			
Yes		397	179 (45.08%)	1.15 (0.71- 1.87)	0.54		
Disability (Same person had multiple disabilities)							
Locomotor	No	349	162	Reference			
	Yes	130	51 (39.2%)	0.74 (0.45–1.3)	0.27		
Hearing	No	458	467	Reference			
	Yes	21	12 (57.1%)	1.45 (0.95–1.94)	0.34		
Visual	No	437	457	Reference			
	Yes	42	22 (52.3%)	1.36 (0.35- 2.37)	0.23		

The living status of older adults is another crucial risk factor identified in our study. Living with at least one child [OR: 0.374 (0.208–0.674); *P*-value: < 0.001] and living with a spouse [OR: 0.529 (0.485–0.573); *P*-value: 0.004] were found to be protective in univariate analysis. However, in multivariable analysis, only living with at least one child was significant [AOR: 0.333 (0.186–0.597); *P*-value: 0.025]. A cross-sectional study from rural Tamil Nadu also found that living with children (O$R = 0.86$, 95% CI = 0.77–0.97) protects older adults from depression (15). Other studies from different countries had varied results. A study from the migrant Russian population in the USA identified that older adults living alone only had depression while living with spouses or children were relatively protected from depression. Another study from China showed significant protection from depressive disorders only when the older adults lived with a spouse ($r = 0.141$), and the older adults living with children were more depressed ($r = 0.189$) (47). In Spain, not living with children was significantly associated with more depressive symptoms [unstandardized coefficient: 3.5 (0.9)], while living with children reduced depressive symptoms [unstandardized coefficient: 1.5 (0.8)] (48). The difference seen in different countries can be due to the cultural variations in each place. The SHARE study in Europe found that in areas where three-generation families are prevalent, the presence or contact with children is more important than that of a spouse or partner for the mental health of older adults (49). Our study was conducted in rural Odisha, where 37% were from three-generation families. The prevalent culture of rural Odisha consists of three-generation families, where the older adults live with children and grandchildren.

While substance use among family members and elder abuse was found to increase the risk of depression by 16 times and 3 times, respectively, and living with offspring decreased the risk of depression among older adults by 67%. After adjusting for comorbidities, physical activity, and adverse life events, physical dependency for self-care and financial dependency were found to be independent risk factors. Participating in recreational activities reduces depression among older adults by 45%. Strengthening NPHCE through community-based programs to improve the independence of older adults in family life should be prioritized. Furthermore, the mental health of older adults should be addressed from the primary healthcare setting onward, through screening, diagnosis, and management. Moving forward, large multicentric national studies identifying the mental health issues of older adults and studies identifying the temporality of associated factors should be considered.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Institute Ethics Committee, AIIMS Bhubaneswar. The patients/participants provided their written informed consent to participate in this study.

Conclusion and recommendations

The study identified depression among 44% of older adults in rural Odisha, which needs to be addressed in the National Program for Health Care of the Elderly (NPHCE) through primary care settings. Quality of family life and independence were major factors affecting depression among older adults of rural Odisha.

Author contributions

AA: conceptualized the study with expert guidance and supervision from SPP and PB. AA: wrote the protocol, conducted the study, conducted the statistical analysis and drafted the initial protocol with inputs from SPP, PB, and SKP. All authors participated in interpreting the data and reviewed successive drafts

of the manuscript for the intellectual content, read, and approved the final manuscript.

Conflict of interest

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

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Association between living environmental quality and risk of arthritis in middle-aged and older adults: a national study in China

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Background: The association between combined environmental factors and the risk of arthritis is still scarcely studied. The present study performed cross-sectional and cohort studies to explore the association between risk score of living environment quality and the risk of arthritis in middle-aged and older adults in China.

Methods: The study was based on China Health and Retirement Longitudinal Study (CHARLS), and it recruited 17,218 participants in the cross-sectional study and 11,242 participants in the seven-year follow-up study. The living environment quality was measured by household fuel types, household water sources, room temperature, residence types, and ambient concentration of PM2.5. Logistic regression and Cox proportional hazard regression models were utilized to examine the association between the living environment quality and the risk of arthritis. Competing risk models and stratified analyses were applied to further verify our results.

Results: Compared with individuals in the suitable environment group, people who lived in moderate (OR:1.28, 95%CI: 1.14−1.43) and unfavorable environments (OR:1.49, 95%CI:1.31−1.70) showed higher risks of arthritis when considering the multiple living environmental factors (P for trend <0.001) in the cross-sectional analysis. In the follow-up study, similar results (P for trend=0.021), moderate environment group (HR:1.26, 95%CI:1.01−1.56) and unfavorable environment group (HR: 1.36, 95%CI: 1.07−1.74), were founded.

Conclusion: Inferior living environment might promote the development of arthritis. It is necessary for the public, especially old people, to improve the living environment, which may be the key to the primary prevention of arthritis.

KEYWORDS

living environment quality, arthritis, cross-sectional study, cohort study, incidence

1. Introduction

Arthritis is one of the most common chronic diseases and often presents with joint pain, immobility, and even joint conformity, people who suffer from arthritis may feel weakness, low self-efficacy, and social isolation, people who suffer from arthritis may feel weakness, low self-efficacy, and social isolation (1, 2). The two most common types are osteoarthritis

and rheumatoid arthritis (RA). There are 355 million people with arthritis worldwide, of which 190 million have osteoarthritis, and over 16.5 million have rheumatoid arthritis (3, 4). As a leading global burden of disease, it was reported that arthritis caused a significant financial and healthcare burden in the United States in 2013 (5). According to the statistics, there are now over 100 million arthritis patients in China, half of the population aged 50 or above in China suffer from osteoarthritis and the number is increasing steadily (6, 7). In this social circumstance, it is very important to explore the risk factors of arthritis, which can be beneficial to the prevention of arthritis.

The origins and pathological causes of arthritis are complex and multifactorial, with only a limited number of factors identified as playing significant roles in its occurrence and development, including genetics and environmental factors (8–10). There were major genetic associations with the HLA locus, while multiple non-HLA genetic variants showed a relatively lower risk of RA (9). Air pollutants, including $PM_{2.5}$ and PM_{10}, have been linked to the incidence of arthritis (11, 12), and recent studies suggest that household solid fuel may pose an even greater risk. Additionally, household water sources have been implicated in the incidence of osteoarthritis (13). While living building environments, including factors such as building type, temperature, conditions, and humidity, have been studied less extensively in relation to arthritis, they can still have negative impacts on human health (14). Building type, in particular, has been associated with arthritis and is often viewed as a reflection of social and economic status (15). However, a comprehensive measurement of living quality is still uncovered.

Nowadays, most studies only paid concern to the effect of a single environmental factor that partially represents the real-living environment on arthritis. Those environmental factors could be interrelated and might have offset effects and synergistic effects on arthritis. But no related studies focused on this complex effect of multiple environmental factors on arthritis. Recently, combining multiple environmental factors, an overall quality score of the living environment was reported to have the potential to evaluate the quality of human living quality comprehensively (16). To mimic real living conditions, we included household fuel types, household water sources, room temperature, building types, and ambient concentrations of $PM_{2.5}$ in the living environment factor score, and further assessed its effect on arthritis. All data were based on the China Health and Retirement Longitudinal Study.

2. Methods and materials

2.1. Study population

CHARLS is an ongoing national cohort study that recruited 17,708 participants who were successfully investigated from more than 10,000 households in 2011, the profile has been fully described elsewhere (17). Each follow-up was biennially conducted, which mainly included assisting face-to-face interviews assisted by a computer-assisted personal interviewing (CAPI) system. In the current study, we analyzed the available data from 2011 to 2018 and designed cross-sectional and longitudinal studies to detailly tap into the association between living quality and arthritis. We excluded 433 participants who had missing data on living environment factors and 57 failed to complete the information on arthritis. Thus, 17,218 participants were available in the cross-sectional study. In the longitudinal study, 11,242 participants were included after excluding 5,976 arthritics patients who had arthritis at baseline (Figure 1). This study adhered to the guidelines of the Declaration of Helsinki, and the protocol was approved by the Ethical Review Committee of Peking University (approval number: IRB 00001052-11015), and informed consent was provided by each participant.

FIGURE 1
Flow diagram for participants enrolled in the study.
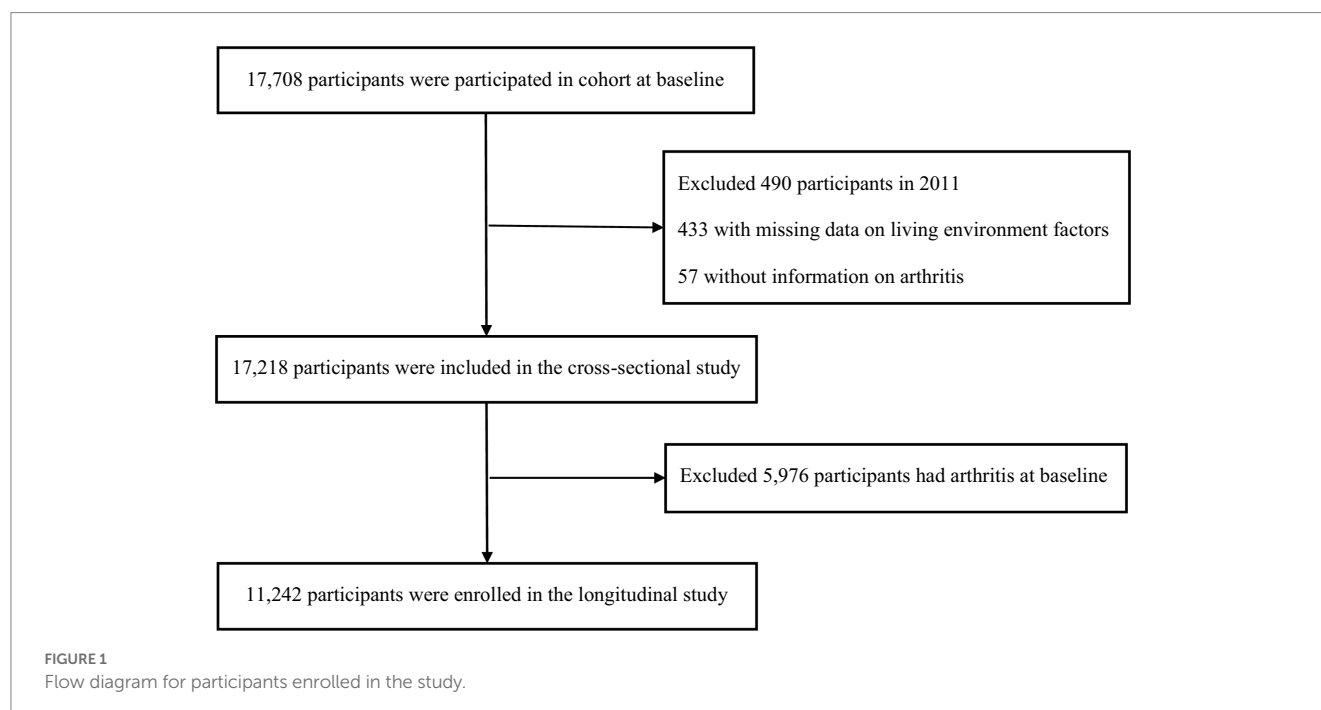
2.2. Assessment of living environmental quality

The living environmental quality was mainly defined from five aspects, including atmospheric particulate concentration, domestic fuel types, household water sources, type of accommodation, and room temperature, which had been fully examined (16). The National Aeronautics and Space Administration Earth Observing System Distributed Information System published the annual average values of city-level $PM_{2.5}$. To be specific, both the Goddard Earth Observing System chemical transport model and the geographically weighted regression model were conducted to calculate the ambient concentrations of $PM_{2.5}$, according to the aerosol optical depth data extracted from multiple satellites (18). According to the guideline, which was issued by the Ministry of Ecology and Environment of China, $35 \mu g/m^3$ was determined as a cut-off value for a high level of $PM_{2.5}$. Household fuel use for cooking and heating is the main source of indoor air pollution (19), the fuel types were further divided into two groups: clean (natural gas, marsh gas, liquefied petroleum gas, and electric for cooking; natural gas, liquefied petroleum gas, solar energy, electric, and municipal heat for heating), or solid fuels (coal, crop residue, wood, and solid charcoal for cooking; crop residue, coal, wood, and solid charcoal for heating). Furthermore, the information on building types and household water sources was collected through a standardized questionnaire, which was assisted by the CAPI system. On the other hand, interviewers got permission from the house owner entranced the house and recorded the level of temperature on the personal computer. Five levels were recorded including very hot, hot, bearable, cold, and very cold. If the temperature disturbed people, we determined it unfavorable, otherwise, suitable was implemented.

The scoring method and algorithm have been detail tabulated in Table 1.

2.3. Assessment of arthritis

The diagnosis of arthritis relies on a multi-assessment, including various clinical symptoms and imagelogical examination, and is often evaluated by a physician. In the current study, due to the data limitations, the diagnosis of arthritis was mainly based on a previous study (20). During the baseline survey, participants were asked if they had received a clinical diagnosis of arthritis from a physician. If the response was affirmative, the interviewer inquired about the onset time and recorded the information. During follow-up surveys, participants were asked to confirm the accuracy of their previous responses, and the interviewer then asked whether they had been diagnosed with arthritis since the last survey. If a patient was confirmed, the diagnostic time was recorded.

2.4. Assessment of covariates

The basic information of individuals on age, gender (male, female), residence (urban, rural), living with a spouse (yes, no), participating in social activity (active, inactive), annual household income (<10,000, 10,000–20,000, >20,000), education levels (illiterate, elementary school, middle school, high school or above), smoking (never, ever, current), drinking status (never, abstainer, current drinker) was collected by trained interviewers with a structured questionnaire. The category of the province was

TABLE 1 The definition of living environmental quality score.

Component	Score of each component	Method of measurement
Household fuel types		Measurement: Self-reported household fuel types
All clean fuel	0	Examples of heating fuel measurement:
Mixed-fuel use	1	"Does your residence have heating?"
All solid fuel	2	"What is the main heating energy source?" Examples of cooking fuel measurement: "What is the main source of cooking fuel?"
Household water source		Measurement: Self-reported household water sources
Tap water use	0	Examples tools for measurement:
Non-tap water use	1	"Does your residence have running water?"
Room temperature		Measurement: Interviewer-observed household temperature
Suitable	0	Examples tools for measurement:
Unfavorable	1	[Interviewer records it] How is the temperature in this household?
Building type		Measurement: Self-reported building types
Multi-story building	0	Examples tools for measurement:
One-story building	1	"Is the building one story or multi-level building, how many stories?"
Ambient concentration of $PM_{2.5}$		Extracted from the NASA Earth Observing System Distributed Information System
$PM_{2.5}$ (<35 ug/m³)	0	
$PM_{2.5}$ (≥35 ug/m³)	1	
Living environmental quality	Accumulation above points	The higher the score, the worse the living environmental quality

NASA, National Aeronautics and Space Administration.

confirmed by the location of each participant. Medically trained personnel from the Chinese Center for Disease Control and Prevention collected and stored venous blood samples at −80°C. Capital Medical University's Youanmen Center for Clinical Laboratory measured glucose (20). And they also performed the physical emanation for participants. Body mass index was calculated by a formula: BMI = weight(kg)/height^2(m^2), and divided into three groups according to the numerical value [normal: 18.5–24.0; thin: <18.5; overweight: ≥24.0 (21)]. An automated electronic device (OMRON Model HEM-7112, Omron Company) was used to measure the diastolic and systolic blood pressures three times on all participants' left arms with an interval. The average of three blood pressures was calculated for the analysis. Individuals were defined as having hypertension if they self-reported physician-diagnosed hypertension, and /or their systolic blood pressures were more than 140 mmHg, and/or the diastolic blood pressures exceeded 90 mmHg (22). The levels of blood glucose were measured by the glucose oxidase method. Diabetes was evaluated by postprandial plasma glucose of more than 200 mg/dL, and/or fasting plasma glucose of at least 126 mg/dL, and/or self-reporting physician-diagnosed diabetes (23).

2.5. Statistical analysis

The participants were allocated into three groups which were defined according to the tertiles of living environment quality score. Means ± standard deviations (SDs) were used to describe the continuous variables and the numbers (percentages) were used to display the categorical variables. The differences in the baseline information were compared by an analysis of covariance or a chi-square test as appropriate. To examine the association between living environmental quality and arthritis risk in these two studies, we conducted two kinds of models. The logistic regression models were performed to evaluate odd ratios (ORs) with 95% confidence intervals (CIs) in the cross-sectional. While for the longitudinal study, Cox proportional hazards models with age as the time scale were established to evaluate hazard ratios (HRs) with 95% confidence intervals (CIs). Moreover, we verified whether the Cox proportional hazards model with Schoenfeld residuals met the proportional hazard assumption before establishing these models. In addition, numeric values were assigned to the tertiles of living environmental quality score and then analyzed as a continuous variable in all models to observe the trend risk between living quality and arthritis.

Stratified and interaction analyses were conducted to confirm such associations based on sex, residence, marital status, participating in social activity, hypertension status, diabetes status, annual household income, education level, body mass index, smoking status, and drinking status. Furthermore, to account for the competitive risk of death on the association between living environment and arthritis incidence, the fine and gray model was performed to reanalyze the primary results. Considering the importance of the latest WHO recommendations of PM$_{2.5}$, we reconstructed the living environment score and re-run the statistical analysis (24). In addition, we further examined the association between each factor of living environment factors, and then summarize the weighted effect size (25) as the new living environment quality score to re-analyses the primary results. In

addition, the missing data were imputed using multiple imputations, using 5 replications and chained equations in R Multiple imputations (MI). In 1–3 models, the suitable environmental group was regarded as the reference group, and all the potential confounding (age, sex, residence, marital status, education level, annual household income, BMI, participating in social activity, hypertension, diabetes, and province) were gradually fully adjusted.

All analyses were performed by using Stata version 17.0 (Stata Corp, Texas, United States) and R version 3.6.2 (R Core Team, R foundation for statistical Computing, Vienna, Austria). A two-sided p-value <0.05 was defined as statistical significance in all analyses.

3. Results

3.1. The baseline characteristics of study participants

The baseline characteristics of the study population are shown in Table 2 and Supplementary Table S1. A total of 17,218 individuals averagely aged 59.06 (10.14) years were included in the cross-sectional study, and 5,976 participants of them had arthritis. During an average of 7 years of follow-up, 982 new-onset arthritis were documented among 11,242 participants, which indicated an incidence rate of 8.73%. Compared with people living in suitable environments, the participants living in a worse environment were more likely to have low socioeconomic status, be isolated from society and live in rural. Meanwhile, people living in worse environments had a heavy burden of chronic diseases.

3.2. Associations between the living environmental quality score and arthritis in the cross-sectional study

Table 3 indicated that the prevalence of arthritis was 34.66% (5,967/17,218) in total populations, and 26.92% (1,164/4,323), 36.03% (2,285/6,342), and 38.56% (2,527/6,553) were, respectively, corresponding to the suitable environmental group, moderate environmental group, and unfavorable environmental group. In the trend analyses, we demonstrated that a positive link between arthritis risk and the living environmental quality score (OR: 1.21, 95%CI: 1.14–1.29) does exist after controlling for potential confounders, which means higher arthritis risk if people lived in worsen environmental quality (P for trend <0.005). In the univariate analysis, people living in a moderate environment (OR:1.53, 95%CI: 1.40–1.67) and unfavorable environment (OR:1.71, 95%CI: 1.57–1.86) were more likely to have arthritis compared to those living in a suitable environment. After adjusting all covariates such as demographic factors, socioeconomic information and health-related variates in the current study, relative to the participants living in a suitable environment, individuals living in moderate (OR:1.28, 95%CI: 1.14–1.43) and unfavorable environments (OR:1.49, 95%CI: 1.31–1.70) was still associated with a higher risk of arthritis (All P for trend<0.05.). In the stratified and interaction analyses, though the education level and drink status modified the association between the living environmental score and arthritis, the main effects were not materially changed (Supplementary Table S7).

TABLE 2 Baseline characteristics of participants.

Characteristic	Total	Living environmental quality			p-value
		Suitable (0−1)	Moderate (2−3)	Unfavorable (4−6)	
N	17,218	4,323	6,342	6,553	
Age (years)	59.06 ± 10.14	58.28 ± 10.15	58.62 ± 9.99	59.99 ± 10.20	<0.001
Female, n (%)	8,972 (52.11)	2,292 (53.02)	3,307 (52.14)	3,373 (51.47)	0.286
Rural, n (%)	13,196 (76.64)	1,747 (40.41)	5,234 (82.53)	6,215 (94.84)	<0.001
Live with spouse, n (%)	13,813 (80.22)	3,534 (81.75)	5,051 (79.64)	5,228 (79.78)	0.014
Participating in social activity, n (%)	8,521 (49.49)	2,603 (60.21)	3,067 (48.36)	2,851 (43.51)	<0.001
Hypertension, n (%)	6,445 (37.43)	1,573 (36.39)	2,319 (36.57)	2,553 (38.96)	0.005
Diabetes, n (%)	2,301 (13.36)	584 (13.51)	804 (12.68)	913 (13.93)	0.106
Arthritis, n (%)	5,976 (34.71)	1,164 (26.92)	2,285 (36.03)	2,527 (38.56)	<0.001
Annual household income (¥), n (%)					<0.001
<10,000	9,849 (57.20)	2,472 (57.18)	3,491 (55.05)	3,886 (59.30)	
10,000–20,000	2,611 (15.16)	532 (12.31)	998 (15.74)	1,081 (16.50)	
>20,000	4,758 (27.64)	1,319 (30.51)	1,853 (29.22)	1,586 (24.20)	
Education level, n (%)					<0.001
Illiterate	7,770 (45.13)	1,256 (29.05)	2,979 (46.97)	3,535 (53.94)	
Elementary school	3,720 (21.61)	838 (19.38)	1,441 (22.72)	1,441 (21.99)	
Middle school	3,562 (20.70)	1,093 (25.28)	1,295 (20.42)	1,174 (17.92)	
High school or above	2,166 (12.58)	1,136 (26.28)	627 (9.89)	403 (6.15)	
Body mass index (kg/m²), n (%)					<0.001
Normal	8,511 (49.43)	1914 (44.27)	3,235 (51.01)	3,362 (51.30)	
Thin	1,473 (8.56)	213 (4.93)	562 (8.86)	698 (10.65)	
Overweight	7,234 (42.01)	2,196 (50.80)	2,545 (40.13)	2,404 (38.04)	
Smoking status, n (%)					<0.001
Never	10,415 (60.49)	2,806 (64.91)	3,855 (60.79)	3,754 (57.29)	
Ever smoker	2,020 (11.73)	502 (11.61)	717 (11.31)	801 (12.22)	
Current smoker	4,783 (27.78)	1,015 (23.48)	1,770 (27.91)	1,998 (30.49)	
Drinking status, n (%)					0.468
Never	10,146 (58.94)	2,584 (59.79)	3,751 (59.15)	3,811 (58.16)	
Abstainer	1,421 (8.25)	349 (8.06)	510 (8.03)	562 (8.58)	
Current drinker	5,651 (32.81)	1,390 (32.15)	2,081 (32.81)	2,180 (33.27)	
Household fuel types, n (%)					<0.001
All clean fuel	5,567 (32.33)	3,956 (91.51)	1,543 (24.33)	68 (1.04)	
Mixed-use of clean and solid fuel	4,618 (26.82)	367 (8.49)	2,964 (46.74)	1,287 (19.64)	
All solid fuel	7,033 (40.85)	0 (0.00)	1,835 (28.93)	5,198 (79.32)	
Non-tap water, n (%)	6,495 (37.72)	101 (2.34)	1,683 (26.54)	4,711 (71.89)	<0.001
Unfavorable room temperature, n (%)	2,841 (16.50)	178 (4.12)	839 (13.23)	1,824 (27.83)	<0.001
One-story building, n (%)	10,465 (60.78)	468 (10.83)	4,014 (63.29)	5,983 (91.30)	<0.001
Ambient PM$_{2.5}$ ≥ 35 ug/m³, n (%)	9,068 (52.67)	1,586 (36.69)	3,124 (49.26)	4,358 (66.50)	<0.001

Values were means ± SD or n (percentages) or median (%).
Values of polytomous variables may not sum to 100% due to rounding.

TABLE 3 Cross-sectional association between living environmental quality score and risk of arthritis in different models.

Living environmental quality	Number of arthritis	Prevalence	OR (95% CI)			
			Crude model*	Model I[†]	Model II[‡]	Model III[§]
Continuous quality score	5,976	34.66%	**1.28 (1.23, 1.34)**	**1.17 (1.11, 1.22)**	**1.14 (1.08, 1.20)**	**1.21 (1.14, 1.29)**
Categorized quality score						
Suitable	1,164	26.92%	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Moderate	2,285	36.03%	**1.53 (1.40, 1.67)**	**1.32 (1.20, 1.45)**	**1.31 (1.18, 1.45)**	**1.28 (1.14, 1.43)**
Unfavorable	2,527	38.56%	**1.71 (1.57, 1.86)**	**1.41 (1.28, 1.56)**	**1.35 (1.21, 1.50)**	**1.49 (1.31, 1.70)**
P-trend			**<0.001**	**<0.001**	**<0.001**	**<0.001**

OR, odd ratio; CI, confidence interval; BMI, body mass index. *Adjust for None.
[†]Adjust for Age (years), Gender (Male, Female), Residence (Urban, Rural), Marital status (Live without a spouse, Live with a spouse), Education level (Illiterate, Elementary school, Middle school, High school or above), and Annual household income (<10,000, 10,000–20,000, >20,000).
[‡]Further adjust for BMI (Normal, Thin, Overweight), Smoking status (Never, Ever, Current), Drinking status (Never, Abstainer, Current), Participating in social activity (No, Yes), Hypertension (No, Yes), and Diabetes (No, Yes).
[§]Additionally adjusted for Province (Categorized by name of each province).
Bold value means the results are statistical significant.

TABLE 4 Longitudinal association between living environmental quality score and arthritis in different models.

Living environmental quality	Number of arthritis	Incidence rate per 1,000 person-years	HR (95% CI)			
			Crude model*	Model I[†]	Model II[‡]	Model III[§]
Continuous quality score	982	13.56	**1.23 (1.14, 1.33)**	**1.15 (1.05, 1.26)**	**1.12 (1.02, 1.24)**	**1.14 (1.02, 1.29)**
Categorized quality score						
Suitable	207	9.95	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Moderate	376	14.35	**1.44 (1.22, 1.71)**	**1.30 (1.08, 1.57)**	**1.30 (1.07, 1.59)**	**1.26 (1.01, 1.56)**
Unfavorable	399	15.69	**1.57 (1.33, 1.86)**	**1.38 (1.13, 1.67)**	**1.33 (1.08, 1.63)**	**1.36 (1.07, 1.74)**
P-trend			**<0.001**	**0.003**	**0.018**	**0.021**

HR, hazards ratio; CI, confidence interval. *Adjust for Age as time scale.
[†]Adjust for Age as time scale, Gender (Male, Female), Residence (Urban, Rural), Marital status (Live without spouse, Live with spouse), Education level (Illiterate, Elementary school, Middle school, High school or above) and Annual household income (<10,000, 10,000–20,000, >20,000).
[‡]Further adjust for BMI (Normal, Thin, Overweight), Smoking status (Never, Ever, Current), Drinking status (Never, Abstainer, Current), Participating in social activity (No, Yes), Hypertension (No, Yes), and Diabetes (No, Yes).
[§]Additionally adjusted for Province (Categorized by name of each province).
Bold value means the results are statistical significant.

3.3. Associations between the living environmental risk score and arthritis at follow-up 2011–2018

Table 4 shows that during a median of seven-years follow-up, 982 arthritis was recorded. The incidence per 1,000 person-years was also calculated in each group. The incidence of arthritis was 13.56 per 1,000 person-years in the entire cohort. The incidences of arthritis were 9.95, 14.35, and 15.69 per 1,000 person-years in suitable, moderate, and unfavorable environment groups when the score was a categorized variable. The results of the cohort study were basically consistent with the cross-sectional study. In the trend analyses, we found that a positive link between arthritis risk and the living environmental quality score (HR: 1.14, 95%CI: 1.02–1.29) does exist after controlling for potential confounders, which means higher arthritis risk if people lived in worsen environmental quality (P for trend <0.005). When dividing the participants into different groups, the crude and full-adjusted models also showed monotonous increasing trends between arthritis risk and poor living environment (All P for trend <0.05). Individuals living in moderate (HR:1.26, 95%CI: 1.01–1.56) and unfavorable (HR: 1.36,

95%CI: 1.07–1.74) environments met an increased risk of arthritis after adjusting for all potential confounders, compared to the suitable environment group. As shown in Supplementary Table S8, no effect modifier was detected (all P for interaction >0.05) and the results in each stratum largely sided with the primary results, which further examined the stability of our findings. Besides, after considering the competition of deaths in the cohort study, the results in Fine & Grey models were still stable and similar to the major results (Supplementary Table S2). The results are consistent with primary results after weighting effect size as the new living environment quality score and the results were still kept in line with primary results after MI (Supplementary Tables S3, S4). The results are consistent with the primary results after utilizing the WHO recommendations as cutoff points for PM2.5 (Supplementary Tables S5, S6).

4. Discussion

In the present study, both cross-sectional and longitudinal studies found poorer living environmental quality associated with a higher

risk of arthritis. This reminds us that we need to concentrate on the overall living environmental quality, which is beneficial to older people to alleviate the heavy burden of disease.

Indoor air pollution poses a great threat to human health. A higher risk of chronic multimorbidity due to household air pollution was identified in Chinese adults (26, 27). It was reported that about 50% of individuals might choose solid fuels, such as coal, kerosene, and biomass fuels, for domestic use for cooking and heating, especially in some developing countries (28). When these solid fuels are burned, household air pollution came after. One study from WHO has indicated that household air pollution might result in about 2 million deaths per year (29). Recently a nationwide population-based cohort study showed that the incidence of arthritis was lower among clean fuel users than solid fuel users, as a concrete manifestation of comparing to clean fuel users, cooking and heating with solid fuels had a relatively higher risk of arthritis (28). Another cohort study demonstrated the same trend for cooking with solid fuel compared with cleaner fuel (20). Meanwhile, a cross-sectional study comprehensively showed that the use of gas, coal, wood, or biomass fuels for cooking was greatly associated with increased odds of arthritis, compared to electricity (30). Those evidences hinted us we need to incorporate household fuel types as one of the important elements to estimate the comprehensive living environmental quality. People consider it difficult to afford the high cost of clean fuel used domestically, especially for an economically underdeveloped country like China. Thus, they prefer cheap fuel types and cleaner fuel use may be a barrier to tackling the health burden (31). which means the process of switching from solid fuel to clean one can be chronic and indicates the household fuel types is relatively stable. Solid fuels play a leading role in heating in northern China (32). and improving income levels is not predicted to alter the pattern of mixed use of multiple fuels in China (33, 34). This evidence elucidated that unhealthy energy is a long-term lifestyle habit that often persists over a lifetime.

Water is a basic need of life and the quality of used water was identified as a leading factor involved in the pathogenesis of many diseases. A follow-up study has already indicated that individuals suffered from complaints and symptoms after household water contamination (35). Household water use was often polluted by heavy metals and many other kinds of toxic elements (36, 37). Tap water in residences is always uniformly filtered by the government so that it tends to be healthier than other water sources such as groundwater and well water. To the best of our knowledge, most studies mainly focused on the effect of water contamination and arsenic exposure on human health (38, 39). Only one study showed that drinking spring water and the well water was associated with a higher risk of osteoarthritis compared to drinking tap water. These studies indicated household water sources play an essential in people's everyday life and impact residents' health. However, the use of water sources was often mixed, so further studies are supposed to explore the specific mechanisms of the development of arthritis.

When climate change came into the researcher's eyes, it was confirmed to be a major contributor to arthritis (13). The physiological functions of the human body could be directly influenced by temperature changes and the incidence of illness and mortality related to cold and heat stress might increase significantly. A meta-analysis reported that climate change may influence the clinical care and pain reporting of patients with RA (40). Likewise, one study from China reported that temperature decrease was significantly associated with RA admission

(25th percentile of temperature vs. 50th percentile of temperature), with the acute and largest effect at current days lag (41). Another retrospective cohort study showed minimum temperature has promoted effect on the pain of rheumatoid arthritis (42). In contrast, fewer studies focused on the association between indoor room temperature and arthritis. An internet-based case-crossover study in the United States demonstrated that higher temperatures were related to approximately 40% higher risk of a gout attack, a chronic disease with inflammatory arthritis, compared to moderate temperatures (43). In basic research, a mouse model with Chikungunya (CHIKV) infection and arthritis showed that CHIKV replication and foot arthropathy were reduced by housing at 30°C compared to 22°C (44). In our study, the unfavorable temperature in the residence was considered a potential risk factor for arthritis. However, certain measured values for household temperature could not be obtained, so more studies were still supposed to assess the effects of indoor room temperature on arthritis.

Air pollution is a major environmental risk to public health. Almost the whole global population is exposed to air pollution which exceeds the standard of World Health Oganization (WHO) for $PM_{2.5}$. The specific mechanisms behind air pollution-caused arthritis might include increased oxidative stress, epigenetic modifications, and systemic inflammation induced by exposures and immune response (45). Recently a case-crossover study including 888 patients with RA showed a striking association between air pollution and the severity of RA and reactivations. Higher levels of air pollutants were associated with increased C-reaction protein (CRP) levels and a higher risk of RA flare. Consistently, several studies from various countries have indicated the correlation between $PM_{2.5}$ exposure and arthritis risk. A study including 722,885 individuals in Taiwan showed an increased risk of developing RA in exposure to $PM_{2.5}$ (12). Meanwhile, a time-series study demonstrated that high-concentration $PM_{2.5}$ was associated with RA remission (46). One animal study also showed a significant effect of exposure to particular matters (PMs) and PMs gaseous exposure with osteoarthritis in rats (47). However, some studies showed that air pollution might not be associated with the risk of RA. A systemic meta-analysis demonstrated that there was an inverse effect between $PM_{2.5}$ and arthritis (48). Results from the Swedish Epidemiological Investigation of Rheumatoid Arthritis (EIRA) case–control study also showed that PM_{10} was not associated with the increased risk of RA (49). Similarly, another study from Taiwan showed, among four quantiles of $PM_{2.5}$ concentration, demonstrated a risk trend between $PM_{2.5}$ and RA although the results were statistically insignificant (50). In our study, higher $PM_{2.5}$ concentration was listed as a potential risk factor in the environmental score to estimate the overall living environment and its effect on arthritis. Those results indicated a complex association between PMs and arthritis. Different types of arthritis may have different relations to exposure to $PM_{2.5}$. For example, the correlation between rheumatology arthritis and exposure to $PM_{2.5}$ may differ from osteoarthritis. As one recent study reported that the models with 89% weighting the late-stage (>40 years) indicated $PM_{2.5}$ exposure was not associated with gout or osteoarthritis (51). However, the results remain controversial. Many studies indicated the detrimental effect of $PM_{2.5}$ on overall arthritis (30, 52). Indeed, future studies need to explore the relationship between specific arthritis and $PM_{2.5}$ exposure and identify the association between our score and specific arthritis. Any extrapolation on the association between the score and specific types of arthritis based on our study should be careful.

The environments of the living and working buildings were reported to impose an effect on human health. Whereas, few studies focused on the role of the built environments of various neighborhoods in the development of arthritis. Most concentrated on the impact of the built environment on physical activity and pain in arthritis patients. Results of the 2015 National Health Interview Survey Data showed that less than a highly-walkable neighborhood and lower social cohesion were independently associated with decreased odds of meeting physical activity recommendations among adults with arthritis and recent joint pain (53). Another scope review revealed that a neighborhood-built environment was very important for supporting osteoarthritis self-management, especially for facilitating physical activity (54). One cross-sectional study in Finland, Poland, and Spain demonstrated that the improvement of neighborhood features could facilitate the mobility of the aging population, with evidence of benefits for health (55). What's more, people living in older households tended to have abnormal clinical features of ankylosing spondylitis, compared to people who lived in buildings that were developed in 1990 or after (56). Moreover, specific attributes of the neighborhood-built environment were greatly associated with physical activity in older people with lower limb osteoarthritis than those without it (57). The influence of the type of housing on arthritis is still obscure. A study from China has investigated the association between the environment of buildings, including types of buildings, and self-reported health status (58). That study found living in a multi-story building was a risk factor for health-related challenges compared to residing in a single-story house and high-rise elevator buildings among older persons. In the present study, it was reported that living in a single-story building, compared to living in a multi-story housing, was listed as a potential risk factor associated with a greater risk of arthritis. The discrepancy may vary across ages and differ by different outcomes. It was reported that the older population living in rural areas and staying at lower socioeconomic status was supposed to suffer from arthritis (14). This phenomenon is more common in China, multi-floor housings were very popular in urban areas since the 1950s, they were built by the government and used for nation-owned companies' work units for their laborers to live in; however, many people from disadvantaged backgrounds still tent to live in single-story buildings at that time (59).

The environment of human living was very complex and filled with indoor and outdoor pollutants. Numerous studies have demonstrated the correlation between a single environmental factor and arthritis. However, studies about the combined effects of various environmental factors were very limited, so it was prompt to explore the integrated risk factors for arthritis in the living environment. To explore the comprehensive environmental exposure in people's living environments, a score combining five different items in our daily life was utilized to evaluate the possible exposure level of every person, simulate to the scores of a healthy lifestyle. Through a cross-sectional and seven-year cohort study, the results of our study showed that there is a detrimental effect of poor environmental living quality on arthritis. In the cross-sectional analyses, education level and drinking status were identified to modify the association between the living environmental score and arthritis, although the trend remained the same as the main results. Education levels are straightly related to working types and environment and reflect socioeconomic status to some degree. Our results indicated that those with higher education levels living in worse environmental quality were supposed to have a

higher risk of arthritis and more attention should be paid to this group. The effect of alcohol consumption on arthritis remained, and its effect on arthritis sustained although people have quit drinking, which means alcohol intake can pose a chronic impact on arthritis. Additionally, the specific alcohol intake was not measured in our study due to the data limitation. Future studies are needed to study how alcohol consumption modified the association between living environmental quality score and arthritis. Nevertheless, the specific mechanisms of how the environment influences arthritis were not studied completely. Many pathways regulated by the pollutants in different media were identified to involve in arthritis responses. For example, pollutants inhaled in the lung could trigger pro-inflammatory or oxidative stress mediators and take part in the internal circulation of the human body. Meanwhile, the imbalance of the autonomic nervous system could be produced by these pollutants. Moreover, some elements of the pollutants might straightly get into the bone and skeletal tissues and participate in the development of arthritis. These pollutants could induce subclinical physiological changes, such as synovium injury, fatigue, movement disorder, vasoconstriction and endothelial dysfunction, which might direct the actual cause of the arthritis event in a single person.

To the best of our knowledge, the present study was the first to analyze the effects of comprehensive living quality on arthritis utilizing the comprehensive score. An integrated environment, including indoor and outdoor environments, as well as chemical elements and physical factors, was estimated to provide the most accurate description of environmental exposures. The findings in our study could well illustrate the casual association according to the cross-sectional and cohort study. Above all, the burden of arthritis was one of the most serious public health problems. Our study could help to discover the high-risk populations and carry out preventive methods timely. However, the present study still has some limitations to notice. First, the diagnosis of arthritis relies on self-reported physician-diagnosed arthritis, which means the number of patients and association of living quality with arthritis may be underestimated. However the diagnostic method was validated, and the statistical results still hold (60). Second, we focused on the association between baseline exposure and arthritis but the exposure may change as time goes by. Therefore, future studies should consider measuring this association more comprehensively. Third, the weighted scores have been used in our study, the results were not changed significantly, and another study proved the validity of the current living environment score (19, 20). Nonetheless, there are still some improvement areas in the algorithm of living environment score due to many other factors also existing in people's living settings. Fourth, although the temperature indoors is relatively steady for humans and has been used in some studies (16), the temperature outdoors is varying across different times, and further studies are needed to elucidate the association between the fluctuation of temperature and arthritis. Fifth, the data on certain types of arthritis was lacking, and the impact of our score on particular arthritis could not be validated in detail and the results may vary. So, any extrapolation about the effect of living environment quality on specific types of arthritis based on this study should be approached with caution although the association between living environment and overall arthritis has been found. And future studies are needed to explore the association between the living environmental quality score and certain types of arthritis. Finally, many confounding factors may still exist although the current study

included many significant confounders including demographic factors, lifestyle, social status, and clinical features.

5. Conclusion

Worse living environmental quality was adversely correlated to arthritis, both in the cross-sectional and the seven-year follow-up studies. We consider it necessary to attract the attention of the public and the government to the importance of spending efforts to improve the living environment.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: All the data can be obtained from the China Health and Retirement Longitudinal Study 2011 to 2018 (http://charls.pku.edu.cn/).

Ethics statement

The studies involving human participants were reviewed and approved by the study protocol was approved by Peking University's Ethical Review Committee (IRB0000105211015). The patients/participants provided their written informed consent to participate in this study.

Author contributions

LG, YL, and RL: designed and devised. YZ, RL, and RG: control. YZ, RL and RG: writing and translation. YL, LG, and YZ: revising and reviewing. 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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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1181625/full#supplementary-material

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Effect of built environment on BMI of older adults in regions of different socio-economic statuses

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Background: Numerous studies have ignored the influence of underdeveloped urban surroundings on the physical health of China's ageing population. Lanzhou is a typical representative of a less developed city in China.

Methods: This study investigated the relationship between body mass index (BMI) and built environment amongst older adults in regions of different socio-economic statuses (SES) using data from medical examinations of older adults in Lanzhou, as well as calculating community built environment indicators for regions of different SES based on multiple linear regression models.

Results: Results showed that age and underlying disease were negatively associated with overall older adult BMI in the study buffer zone. Land use mix, number of parks and streetscape greenery were positively associated with older adult BMI. Street design and distance to bus stops were negatively connected in low SES regions, but population density and street design were negatively correlated in high SES areas.

Conclusion: These findings indicate that the built environment of SES regions has varying impacts on the BMI of older persons and that planners may establish strategies to lower the incidence of obesity amongst older adults in different SES locations.

KEYWORDS

body mass index, built environment, linear regression, older adults, obesity, socio-economic status

1. Introduction

According to the seventh census of the China Bureau of Statistics, the population aged 60 and over in China is 264.02 million, or 18.70% of the total population. With 190.64 million people aged 65 and older, or 13.50% of the population, China will enter a profoundly ageing society (1). Building an appropriate community constructed environment for the older adult is an important need for an ageing society to improve the living environment of the older adult and increase their quality of life. The greatest challenge facing the older adult as the body's functions begin to decline with age is health, especially chronic diseases such as cardiovascular disease, type II diabetes, hypertension and colon cancer (2). Obesity is an important cause of these chronic diseases (3, 4), and it seriously impacts health and quality of life of older adult individuals. Body mass index (BMI) is a commonly used international measure of body fatness and health, and a higher BMI indicates a higher likelihood of being overweight. The BMI of older adults is influenced by some factors, such as built environment (5).

The built environment consists of several components, including land use, transport planning and urban design (6). The built environment has been categorized into five dimensions: density, diversity, design, destination accessibility and distance to transit; they form the 5D model of the built environment (7). The 7D model was developed by introducing demand

management and demographics to quantify the built environment (8). The development of technology in recent years has enabled scholars to add a more comprehensive description of the built environment by introducing normalized difference vegetation index (NDVI) (9, 10) and street-level greenery (11–13). Many studies have shown a substantial correlation between the built environment and obesity (14, 15). The design of built environments may reduce the incidence of overweight and obesity amongst people by offering walkable designs and supporting physical activity and a healthy eating environment (16). Existing studies have focused on the relationship between built environment and BMI by segmenting groups of older adults of different socio-economic statuses (SES) (17, 18). The built environment in high SES areas has less impact on older adult's BMI than in low SES areas, and higher accessibility to public sporting facilities and better public sporting services and road connectivity near where older adults live increase the probability of transport-based physical activity and thus decrease the risk of obesity (19). The density of road intersections, the number of facilities in parks near the place of residence, the number of work and residential exercise facilities and the availability of recreational exercise areas are significantly and negatively associated with BMI levels (20). The built environment of the community has a significant effect on BMI (21).

The presence of public green spaces may provide physical exercise for older adults (22, 23) and can positively impact psychological well-being of older adults (24), all of which may lead to changes in BMI (25, 26). Recent studies have shown that streetscape green ratings are a more objective indicator of the influence of green space on senior citizens (11–13, 27). Therefore, the effect of streetscape greenness on BMI in older adults needs to be explored.

The relationship between the community built environment and health has received attention and research in many developed countries (28). However, most previous research on the relationship between the community built environment and obesity has been conducted in developed western countries. A thorough study of the physical environment factors of adult weight status revealed that Asian nations have undertaken less research on this issue (29). However, these findings are not necessarily applicable to developing countries. Previous studies have mainly focused on more developed cities (30–32), and less in underdeveloped areas, especially industrial cities in underdeveloped areas. In the past, the research on the health of built environment in China's industrial cities focused on more developed industrial cities, such as Tianjin, Wuhan and other developed cities (33). Lanzhou is an important central city in western China. After the reform and opening up of the People's Republic of China, Lanzhou is one of the fastest growing cities in China, an industrial city with distinctive characteristics and an immigrant city. The central urban area of Lanzhou is facing prominent environmental contradictions, and the construction of local environmental facilities cannot meet the physical activity needs of urban residents (34). It has certain representativeness in cities with backward economy compared with developed cities. Research on the relationship between community built environment and BMI based on older age groups is also slightly weak in China's increasing population ageing. As Lanzhou has a large number of immigrants in the process of urban development, the influx of a large number of immigrants in the same period has made the current base of the older adults population in Lanzhou high. The older adults population in Lanzhou accounts for 16.56% of the total population. The characteristics of urban aging are distinct, with a large base, rapid growth, aging and other characteristics. The health

problems of the older adults population in Lanzhou are very worthy of attention.

This study aims to explore the relationship between the built environment and the BMI of older adults in Lanzhou City. It intends to address the following three questions: (1) How does the built environment impact older adults' BMI in Lanzhou? (2) How does the built environment in regions with different socio-economic statuses (SES) affect the body mass index (BMI) of older adults in Lanzhou? (3) How does the street greening rate affect the BMI of older adults in Lanzhou? Through exploring the three questions above, we aim to provide a more objective picture of the impact of the built environment on the BMI of older adults for planners and policymakers to consider when designing for ageing.

2. Literature review

2.1. Research related to the impact of the built environment on the behavior of older adults

Scholars have demonstrated that the built environment can impact human behavior (35) by attracting people to active travel and thus reduce BMI (36). Providing more physically active places, such as pavement design and streets with higher circulation (37, 38), traffic safety (39), aesthetics (40) and good pedestrian infrastructure (39) can promote healthy behaviors (41) and thus reduce BMI. The proximity and availability of facilities associated with physical activity may be necessary for supporting high-intensity physical activity (42). The built environment may substantially affect the physical and mental health of older adults (43–45). In the current study, density (46), diversity (47), accessibility (48), safety (49), green space (50), and aesthetics (51) have all positively influenced BMI in older adults (14).

Green spaces or parks in cities may lower the BMI of older adults, and prior research has shown that more green public places can encourage older adults to engage in physical activity (52–54). Some studies have demonstrated that streetscape green visibility is an important indicator for describing green spaces (55), and it has only been discovered and applied by scholars in recent years to assess the quality of green spaces (56–58). Street green vision is a method of capturing and identifying street-level images to determine the exposure of greenery in a neighborhood, and it provides an objective view of the green environment from a human perspective (13). Studies have found that higher street greenness is associated with a higher propensity for older adults to exercise (12), which in turn reduces obesity (59, 60).

The number and proximity of recreational and transport amenities, such as parks and green spaces, might impact the inclination of older adults to travel and engage in physical activity (54, 61). Distance to a park and distance to a bus stop have been shown to be negatively associated with older adults' activity, and both environmental factors can have a more significant impact on older adults than on younger people (62). In some studies in the Americas, the propensity for older adults to travel was greater when the number of parks was greater. In some studies in Asia, the effect was negative for older adults. A study in Shanghai, China found that an increase in green open spaces such as parks, rivers and squares significantly reduced the BMI of middle-aged and older adults, as did with an increase in the land use mix (2).

2.2. Studies related to the impact of the built environment on BMI in older adults

In urban planning and obesity, the link between BMI and built environment in older age groups is a major concern. Studies have shown that higher neighbourhood density, intersections and services are associated with a decreased obesity risk (63, 64). A prior study showed that walking scores were negatively associated with BMI (14). Increasing the land use mix promotes more leisure trips for older adults living in these areas, which reduces BMI in older age groups (65). Similarly, a long-term longitudinal study found that higher densities of land use for retail, churches and recreational and leisure facilities in the neighborhood were more likely to reduce older adults' BMI (66). Some researchers have found no evidence of an association between neighborhood design and BMI, but most existing studies confirm that street connectivity positively impacts health-related outcomes for residents (67). Cities living in polycentric areas can influence the probability of obesity by affecting movement through multiple pathways (68). Better pedestrian-friendly street design can increase walking and thus reduce BMI in older age groups (69).

Some scholars have demonstrated a facilitative effect of the street environment on the physical activity of older adults in areas with high SES (70, 71). Neighborhoods with low SES lack relevant infrastructure due to pollution, which results in a negative association between the built environment and physical activity in older adults (35). The BMI of older adult groups in low SES regions tends to be higher than that of older adult groups in high SES areas because the latter are better equipped to choose their condition preferences. By contrast, older adults in low SES regions tend to be passively influenced by their environment (72).

The analysis above indicates that research on the influence of the built environment on BMI has concentrated mostly on developed nations and less on developing countries, with the exception of some studies in China that revealed a negative effect of population density on BMI, unlike studies in Europe and America (73, 74). A gap exists in research on the relationship between the built environment and BMI in older Chinese populations, and more research is needed to validate the relationship between BMI and environment in older populations. Existing research in China is insufficient to support the universal application of the theory, and community environment research on low SES populations is few. Therefore, this study aims to explore the influence of the built environment on the BMI of Lanzhou's older population.

3. Materials and methods

3.1. Study setting and sample

This research is based on the 2021 medical examination reports of middle-aged and older adult Lanzhou Community Hospital residents. The survey data included the respondent's health condition and personal information, such as his or her residence, height, weight, age and gender. All personal information was anonymized for protection and confidentiality purposes. Data were collected from a total of 1773 older adults. Fourteen communities were selected in Chengguan and Qilihe districts based on density and socio-economic indicators classified by local housing prices (Figures 1, 2). Figure 3 shows the status of socio-economic indicators for each sample area.

The built environment data within the buffer zones were calculated using open-source street data, POI data and building information data from Gaode Map.[1]

Lanzhou is the capital city of Gansu Province, located in western China. According to the Lanzhou Municipal Bureau of Statistics, during the seventh national census, the population of people aged 65 and above in Lanzhou City accounted for 11.70% of the total population (75). The number of older adults people aged 65 and above in Lanzhou City reached 510,055 by the end of 2020. It accounts for 11.70% of the resident population, which has exceeded the 'aging society' defined by the World Health Organisation. According to the WHO's definition of ageing society, Lanzhou has entered an ageing society (76).

3.2. Measures

BMI: The BMI (kg/m^2) was determined using self-reported height and weight. In this research, BMI served as the dependent and continuous variable.

Built environment: This research examined 10 environmental factors, including the "5Ds" built environment indicator variables of population density, intersection density, land use mix, distance to parks and distance to bus stations (7). Five variables were also considered: number of parks, street connectivity, number of bus stops, number of pedestrian bridges and streetscape greenery. The built environment factors utilized in this study were selected based on a review of pertinent research (77). Land use mix: The average distribution of land use categories was measured to compute the land use mix or entropy. We identified seven land use categories more relevant to senior travel: residential, commercial, office, healthcare, public services, recreation and education (78). The following calculation was made:

$$Land\ use\ mix = -\sum \frac{i * \left[(p_i * \ln(p_i)) \right]}{\ln(n)} \qquad (1)$$

where p_i is the proportion of specified land use to overall land usage.

Green Vision: The quantity of street vegetation observed by pedestrians at eye level was determined using BSV pictures. A sampling point was created every 50 m based on previous studies to acquire street views (13, 55). The Python Open CV library was used to perform deep learning on the captured streetscape images and extract the greenness. The formula was as follows:

$$Green\ view\ index = \sum 4i = 1\ Greenery\ pixelsi\ /\ \sum 4i = 1\ Total\ pixelsi. \qquad (2)$$

Demographic socio-economic indicators: Individual factors such as age, gender, duration of light physical activity and underlying medical conditions were also considered possible extra variables. Underlying conditions included hypertension, diabetes and

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1   https://en.tongdajiaju.cn/maps.html
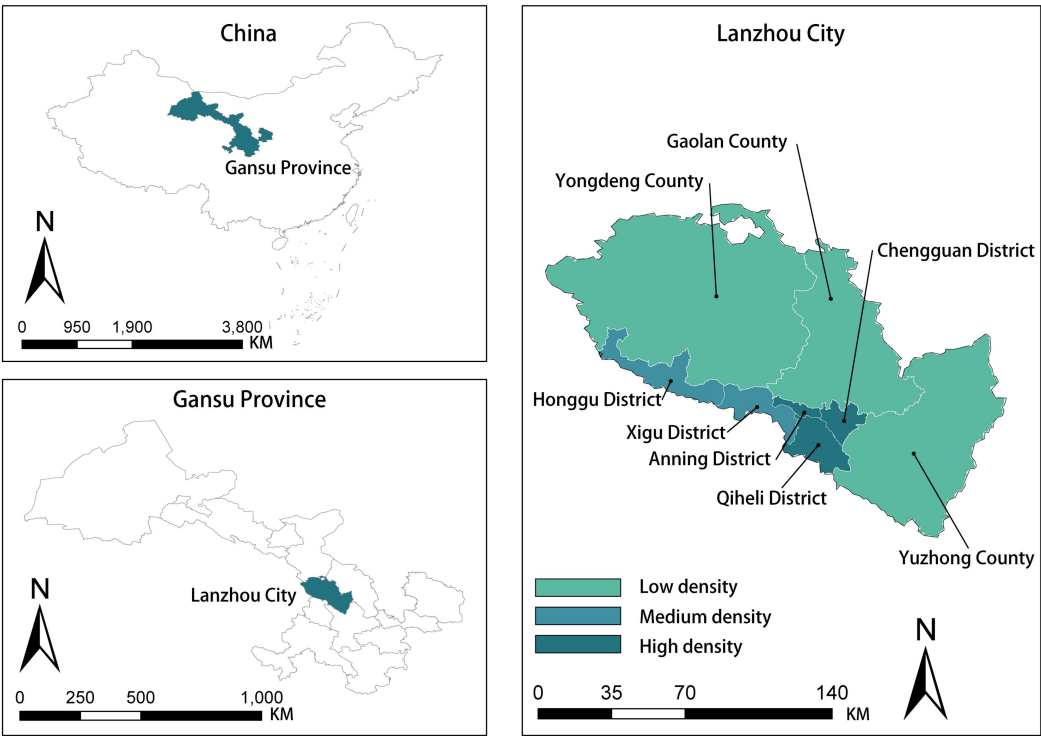
FIGURE 1
Location of Lanzhou City.
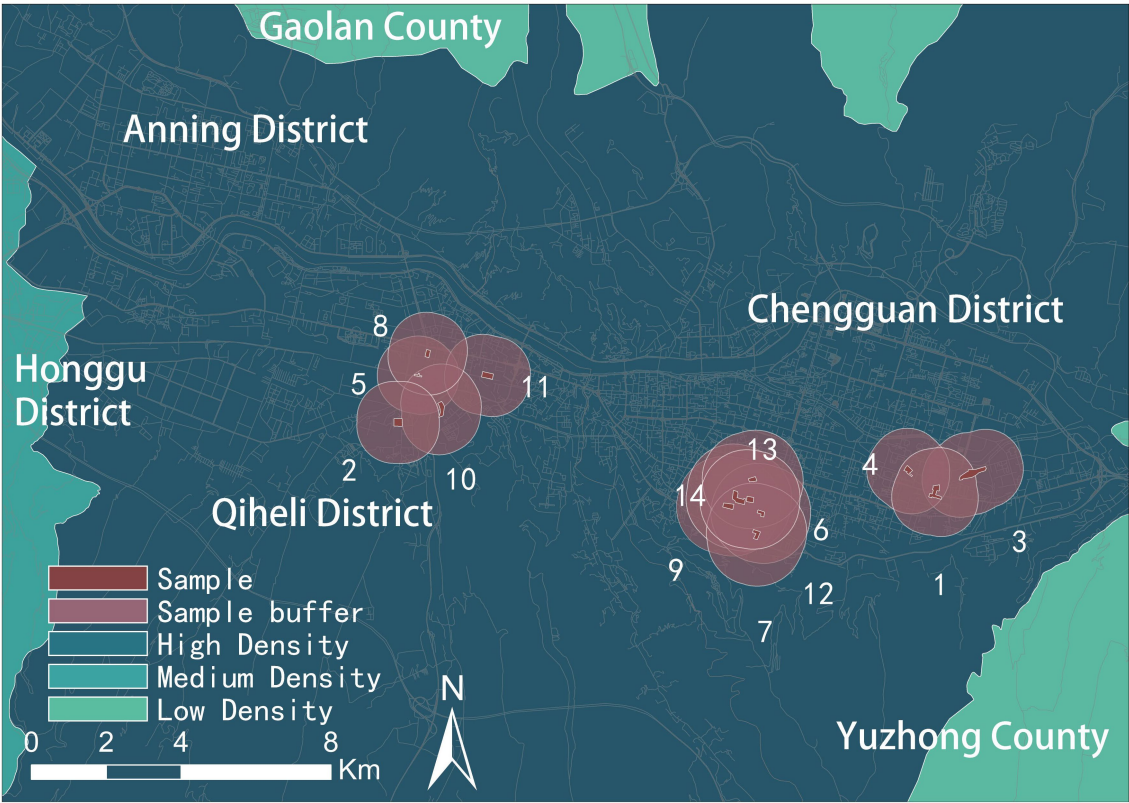
FIGURE 2
Research sample screening diagram.

FIGURE 3
Status of socio-economic indicators for each sample district.

TABLE 1 Descriptive statistics.

Variable	Description	Mean	SD
Dependent variable			
BMI	Dividing the respondent's weight (in kilograms) by the square of the height (in meters)	24.275	3.106
Sociodemograpagic variable			
Gender	Gender of respondents; 1 = female, 2 = male	1.42	0.494
Age	Age of interviewees	71.39	7.733
SES	Socio-economic status; 0 = low SES, 1 = high SES	0.56	0.497
Diseases	Basic disease, such as hypertension and diabetes; 0 = no, 1 = yes.	0.52	0.500
Physical activity	Respondents' reported hours of physical activity per day (in minutes)	84.43	55.031
Built environment variable			
Land use diversity	The proportion of the i-th land use and N is the total number of land use categories. Seven land uses are investigated ($N = 7$): residential, office, commercial, medical, entertainment and public services.	0.653	0.123
Population density	The district's population density (unit: 10^4 persons per km^2)	0.071	0.009
Road intersection density	Density inside a community at a street intersection (unit: $1 km^2$)	26.264	6.454
Street connectivity	Density inside a community at a street intersection (km/km^2)	1.945	0.392
Bus stop distance	The shortest distance between the test site and the bus stop (meter)	124.139	110.604
Park distance	The park is located at the least distance from the sample plot (meter)	319.240	266.534
Number of parks	The number of groups inside a 1 km buffer zone	1.41	0.939
Number of overpasses	The number of overpasses inside a 1 km buffer zone	3.09	1.741
Number of bus stops	The number of bus stops inside a 1 km buffer zone	33.71	9.467
Streetscape greenery	The greenery covering in the BSV photos represents the status of vegetation from the perspective of a pedestrian	0.163	0.022
Sample size	1773		

coronary heart disease. This information was derived from the survey results.

Research method: The linear regression model was used to discuss the relationship between the built environment of the community and the BMI of the older adults. First, Pearson correlation analysis was performed on all variables. Then stepwise regression is performed on the overall area, high SES area and low SES area, respectively. We established three linear regression models. Model 1 tested the impact of the overall community built environment on the BMI of the older adults. Models 2 and 3 distinguished the impact of the built environment on the BMI of the older adults in communities under different SES. All analyzes were performed using SPSS 26.0 (Statistical Products and Services solution). Then, the multicollinearity test was performed on the data, and if VIF < 5, there was no multicollinearity in the data set, and the significance level was set at $p < 0.05$.

4. Analysis

4.1. Descriptive statistics

This research includes information from 1773 individuals; we used univariate descriptive statistics to describe the profile of the study sample. Table 1 lists the information for the present study sample. The average age was 71.3 years old, 57.8% were female, the mean BMI was 24.27 kg/m², 52% had underlying medical conditions and the mean

weekly duration of light physical exercise was approximately 84 min. In the built environment data, the mean value of population density was 0.07 10^4 persons/km², the mean value of land use mix was 0.65, the density of road intersections was 26.26 km², the closest bus stop was 124.13 metres away and the distance to the nearest park was 319.24 m.

4.2. Bivariate analysis of the built environment

Based on the empirical research methods, we also used Pearson to explore the relationship between BMI and the built environment. Table 2 displays the Pearson correlation impacts of the built environment on BMI in the older adults, which is broken down into three sections: (1) the effects in the whole research region, (2) the effects in the low SES area and (3) the effects in the high SES area. In order to explore the impact of the built environment on the BMI of the older adults, a total of three models of Pearson correlation were established, namely the entire study area, low SES area and high SES area. Only the variables that have a significant impact on the BMI of the older adults are shown in the table, and the Pearson correlation of all variables will be shown in the Supplementary Appendix.

Total area of Table 2 shows that, amongst the socio-demographic variables, BMI was positively correlated with disease ($r = 0.210$; $p = 0.000$) and negatively correlated with age ($r = -0.169$; $p = 0.000$). Of the environmental variables, positive correlations were found with population density ($r = -0.068$; $p = 0.004$), intersection

TABLE 2 Pearson's bivariate analysis of built environment and BMI in older adults.

	Total area	Low SES area	High SES area
	R(value of p)	R(value of p)	R(value of p)
Sociodemograpagic variable			
Gender	0.032(0.181)	−0.019(0.602)	**0.082**(0.01)
Age	**−0.169**(0.000)	**−0.164**(0.000)	**−0.155**(0.000)
Diseases	**0.210**(0.000)	**0.223**(0.000)	**0.203**(0.000)
Physical activity	−0.016(0.502)	−0.04(0.269)	0.005(0.884)
Built environment variable			
Land use diversity	0.003(0.887)	0.055(0.122)	0.012(0.697)
Population density	**−0.068**(0.004)	0.002(0.953)	**−0.097**(0.002)
Road intersection density	**0.098**(0.000)	−0.022(0.531)	**0.073***(0.021)
Street connectivity	−0.011(0.644)	**−0.072***(0.045)	0.047(0.142)
Bus stop distance	**0.100**(0.000)	−0.011(0.757)	**0.103**(0.001)
Park distance	**0.067**(0.005)	**0.090***(0.012)	−0.014(0.668)
Number of parks	0.037(0.12)	−0.043(0.231)	**0.106**(0.01)
Number of overpasses	0.014(0.55)	0.025(0.485)	0.013(0.674)
Number of bus stops	**−0.104**(0.000)	−0.066(0.066)	−0.056(0.076)
Streetscape greenery	**0.070**(0.003)	**0.094**(0.008)	0.034(0.305)

$*p < 0.05$; $**p < 0.01$. Bold values represent having relevance.

density ($r = 0.098$; $p = 0.000$), distance to bus stops ($r = 0.100$; $p = 0.000$), distance to park ($r = 0.067$; $p = 0.005$) and Streetscape greenery ($r = 0.070$; $p = 0.003$). It was negatively correlated with the number of bus stops ($r = -0.104$; $p = 0.000$).

Under different socio-economic indicators, age ($r = -0.164$; $p = 0.000$) was negatively correlated, and the prevalence of chronic illnesses was strongly linked ($r = 0.094$; $p = 0.008$) with the BMI of the senior population in the low SES zone. Street connection ($r = -0.072$; $p = 0.044$) and streetscape greenness ($r = 0.106$; $p = 0.001$) were adversely and favourably linked, respectively, with the BMI of the older population in regions with low SES. Within the high SES zone, gender ($r = 0.082$; $p = 0.010$) was favourably related with the impact of BMI in the older age group, whereas age ($r = -0.155$; $p = 0.000$) was negatively associated and having a chronic disease ($r = 0.203$; $p = 0.000$) was positively associated. Population density ($r = -0.103$; $p = 0.001$) was negatively correlated with the BMI of the older adults group in the high SES area; road intersection density ($r = 0.073$; $p = 0.021$), distance to bus stops ($r = 0.103$; $p = 0.001$) and number of parks ($r = 0.106$; $p = 0.001$) all had positive effects on the BMI of the older adults group.

Age and chronic disease effects on BMI in the older adults population were consistent across SES regions. They differed in the variables affecting BMI in the built environment, which is consistent with previous research findings (72).

4.3. Results of the linear regression model

Two sets of linear regression models were built: one for the overall older adult group (Table 3) and the other for the comparison of models under different SES (Table 4). Both models were used to explore BMI in the older adult group. The results for the overall older adult group showed that some environmental variables did not correlate with older adult BMI, and the results of the comparison

studies within different SES regions were different from previous ones.

Amongst the socio-economic indicator variables in their effect on overall older adult BMI, age ($t = -0.129$; $p = 0.000$) was negatively correlated, a finding that differed from previous research and was positively associated with underlying disease ($t = 0.201$; $p = 0.000$). Amongst the effects of built environment variables on overall older adult BMI, land use mix ($t = 3.738$; $p = 0.000$), number of parks ($t = 2.688$; $p = 0.007$), number of flyovers ($t = 2.656$; $p = 0.008$) and streetscape green views ($t = 2.125$; $p = 0.034$) were positively associated with the number of bus stops ($t = -4.99$; $p = 0.000$). The R^2 of the base model was 0.093, which indicates that the base model explained 9.3% of the variance.

Table 4 displays the results of linear regression models examining the influence of the built environment on BMI in the older population under various SES situations. Within the low SES region, age was inversely linked with the impact of BMI in the senior population ($t = -119$; $p = 0.001$), whilst having a chronic condition was favourably associated with BMI in the older adults population ($t = 0.210$; $p = 0.000$); of the built environment variables, road intersection density ($t = -0.110$; $p = 0.043$), distance to a bus stop ($t = -0.140$; $p = 0.008$) and the number of bus stops ($t = -0.161$; $p = 0.005$) were negatively associated with BMI in the older adults group, and distance to a park ($t = 0.206$; $p = 0.000$) was favourably related with BMI in the older adults.

Within the high SES region, gender ($t = 0.080$; $p = 0.008$) and chronic illness ($t = 0.207$; $p = 0.000$) were favourably linked with the impact of BMI in the older age group, whilst age ($t = -0.144$; $p = 0.000$) was adversely associated; population density ($t = -0.140$; $p = 0.000$) was adversely linked with the impact of BMI in the elder group, but street connectivity was favourably associated with BMI in the older adults group ($t = 0.097$; $p = 0.003$). The R^2 of the linear regression model for the low SES region was 0.099, which shows that 9.9% of the

variation was explained by the basic model; the R^2 of the linear regression model for the high SES region was 0.090, which implies that the base model explained 9.0% of the variance.

5. Discussion

In this research, we utilize linear regression to analyze the link between BMI and built environment characteristics in older adults, as well as the influence of built environment variables on BMI in older

TABLE 3 Linear regression model.

Variable	β	t	p-value
(Constant)		19.269	0
Gender	0.036	1.596	0.111
Age	**−0.129**	**−5.575**	**0**
Diseases	**0.201**	**8.75**	**0**
Physical activity	−0.008	−0.352	0.725
Population density	0.022	0.461	0.645
Land use diversity	**0.125**	**3.738**	**0**
Street connectivity	0.037	1.333	0.183
Road intersection density	0.006	0.182	0.856
Distance to park	−0.017	−0.613	0.54
Distance to bus stops	−0.025	−0.777	0.437
Number of bus stops	**−0.178**	**−4.99**	**0**
Number of parks	**0.07**	**2.688**	**0.007**
Number of overpasses	**0.113**	**2.656**	**0.008**
Streetscape green vision	**0.08**	**2.125**	**0.034**

Words in bold are considered as a significant correlation.

adult groups residing in various SES locations. Understanding the influence of the built environment on the BMI of older persons will aid in the design of a community setting that is health friendly for older people.

This research discovers that, at the individual level, the variable of age has a negative connection within the general area and in the low SES and high SES sectors, which means that BMI falls with age in the older age group (79). The regression coefficients for the high and low SES regions show that the BMI of the older adults group in the high SES region tends to decline more rapidly with age than that of the older adults group in the low SES region. This finding is consistent with a study conducted by Zang et al. (80). In general and low SES regions, the influence of gender on the BMI of the older adults population is insignificant. In the high SES zone, the correlation is considerably positive, which implies that males are more likely to have a higher BMI and be obese (81). The group of older adults with underlying conditions show a significant positive association with group BMI in older adults within the overall, low SES and high SES regions, which suggests that having underlying conditions can lead to an increase in BMI (82). In previous studies, performing physical exercise leads to a lower BMI. However, the number of hours of physical exercise performed per day is insignificantly correlated with the BMI of the older population within the overall, low SES and high SES regions in our study. Therefore, performing physical exercise per day does not lead to a decrease in BMI, which is possibly due to the fact that the number of hours of physical exercise performed per day is insignificantly correlated with the BMI of the older population within (80); the number of hours of physical exercise performed per day in this study fails to meet the threshold for influencing changes in BMI (83).

In terms of built environment variables, population density has little effect on the BMI of the older population in the region as a whole. Within the low SES region, population density has reached or

TABLE 4 Comparison of linear regression models for different SES regions.

Variable	β	t	p-value	β	t	p-value
		Low SES			High SES	
(Constant)		19.269	0		22.635	0
Gender	−0.012	−0.352	0.725	**0.08**	**2.637**	**0.008**
Age	**−0.119**	**−3.4**	**0.001**	**−0.144**	**−4.731**	**0**
Diseases	**0.21**	**5.888**	**0**	**0.207**	**6.798**	**0**
Physical activity Min/Day	−0.033	−0.961	0.337	0.014	0.457	0.648
Population density	0.017	0.198	0.843	**−0.14**	**−4.23**	**0**
Land use diversity	0.02	0.325	0.745	0.009	0.283	0.777
Street Connectivity	−0.057	−0.738	0.461	**0.097**	**2.936**	**0.003**
Road intersection density	**−0.11**	**−2.023**	**0.043**	0.021	0.511	0.609
Distance to park	**0.206**	**4.194**	**0**	0.046	1.294	0.196
Distance to bus stops	**−0.14**	**−2.676**	**0.008**	0.039	1.191	0.234
Number of bus stops	**−0.161**	**−2.815**	**0.005**	−0.007	−0.083	0.934
Number of parks	0.058	0.626	0.532	0.044	1.018	0.309
Number of overpasses	0.485	0.584	0.559	0.001	0.028	0.977
Streetscape green vision	−0.034	−0.457	0.648	0.011	0.333	0.739

Words in bold are considered as a significant correlation.

even exceeded the threshold for promoting travel amongst older adults probably due to low SES region (74). Too high population density is a disincentive for older adults to travel (55, 72). But interestingly, there is a significant negative correlation within high SES areas, because higher population density often means more destinations and services within walking distance, more public transport choices and opportunities for social interaction (84). Moreover, high population density is directly related to more walking trips (85). This may be because these factors can promote active travel among the older adults population in high SES areas, thereby reducing BMI (86, 87).

Land-use admixture in the overall model showed a significant positive correlation with BMI in the older adults. The results are inconsistent with studies in some developed countries, where land use mixing was most strongly associated with obesity in Frank's study in the United States (65); and in Saelens' study, people living in communities with high walkability and high land use mixing were associated with lower BMI (88). However, in a study in Hong Kong, land-use admixture was negatively associated with physical exercise in older adults (72); In a study conducted in Shanghai, it was also reported that a negative association between land use mix and physical exercise in older adults (89). Cities with different residential density in different countries may lead to different findings. Therefore, in some cities in China, high land use mixing may reduce the willingness of the older adults to travel, leading to a reduction of physical exercise of the older adults, thus increasing the risk of obesity.

Street connectivity is only positively associated with BMI in older adults in higher SES areas. However, the research demonstrates that street connection has a favorable effect on obesity reduction in densely populated areas (67). The reason may be that better street connectivity can increase the motivation of older adults to walk. However, excessive and complex street connectivity has led to cognitive difficulties for older adults in some studies in China, and this situation reduces their sense of safety and negatively affects their willingness to travel and exercise (90).

Road intersection density is negatively associated with BMI in older adults living in areas with low SES. This result may be due to the fact that high road intersection density improves the travel experience of older adults, which promotes travel and lessens BMI. This finding is coherent with those obtained in some previous studies (80).

Distance to the park is positively correlated with older adults' BMI in areas with low SES, which may be due to that respondents' neighborhoods are far from the park and fail to elicit a willingness to travel. Some Chinese studies have shown that poor park accessibility and susceptibility to noise reduce the attractiveness of parks to older adults (91). A positive correlation exists between the number of parks and the BMI of older adults in the overall region. This finding may be due to the fact that local older adults are accustomed to doing activities in familiar neighborhoods and that local parks provide relatively little space for activities that are not conducive to physical activity.

In locations with low SES, BMI is inversely related with proximity to a bus stop amongst older adults persons. In low SES neighborhoods, the frequency of bus stops is inversely related with BMI amongst older persons. The reason may be the poor accessibility of public transport in low SES areas, which increases the probability of travelling on foot and thus reduces BMI (92).

A positive correlation exists between the number of flyovers and the BMI of older individuals in the whole area. This finding may be due to that too many flyovers cause difficulty for older persons to travel, which negatively affects their desire to do so. In contrast to the finding in earlier research, streetscape greenness is positively connected with BMI amongst older persons in the entire area (34, 53). The reason may be due to the lack of street greenery in the respondent's neighborhood, the inability of green spaces to motivate older adults to exercise and the fact that some of the leisure facilities are situated inside green areas and therefore have no detrimental effect on BMI.

The built environment affects BMI in older adults, and this effect is complex and variable. The results of some studies differ from those of previous works, and more studies of the same type are needed to determine the general applicability of the effect.

6. Conclusion

This research highlights the significance of the built environment in a relatively low SES inland city by using Lanzhou, a typical city in Northwest China, as an example. We verify the relationship by assuming that the overall older population and the older population in regions under different SES have a meaningful relationship with the built environment. We use Pearson correlation and linear regression models.

This study has some limitations and restrictions. We only measured built environment attributes around the respondent's home. However, inhabitants are permitted to go to other locations, such as workplaces and stores. Future research might examine the impact of the built environment on BMI at diverse vacation destinations. Future research might evaluate the combined impacts of physical activity and food environment on obesity given that this study focused only on the community's built environment. We also did not incorporate all pertinent aspects of the built environment, such as traffic and criminal safety (93, 94). This study was not conducted in a nonlinear manner through a linear research with pre-existing assumptions, lacked the relative importance of environmental characteristics and ignored the effect of some environmental factors on BMI in older age groups.

The data indicate that the age of older persons is negatively connected with BMI and positively correlated with underlying disease throughout the whole area. In terms of environmental characteristics, the number of parks and land use diversity correlate positively with BMI, but the number of bus stops correlates negatively. We detect a higher influence of BMI on the built environment in older age groups in low SES areas than in high SES areas. Attention to environmental planning in low SES areas is more likely to help reduce the risk of obesity in older adults. Our research serves as a guide for urban planners and designers to address the health of older individuals in urban planning.

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

Author contributions

PZ: conceptualization. JH: resources. HQ: supervision. HZ: validation. PZ and KC: writing – original draft. KC: writing – review and editing. YY: analysis. 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.2023.1207975/full#supplementary-material

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The effect of internet use on depressive symptoms in middle-aged and older adults with functional disability: the mediating role of social isolation

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Objective: The popularization of the internet provides the possibility to improve the depressive symptoms (DS) and social isolation of middle-aged and older adults with functional disability. There was a significant correlation between internet use and DS in middle-aged and older adults with functional disability, but the relationship between internet use, social isolation, and DS remains to be confirmed.

Methods: Data were obtained from 7,955 middle-aged and older adults aged 45 years and older from the 2018 China Health and Retirement Longitudinal Study (CHARLS). Multiple linear regression models were used to analyze the association between internet use and DS, and the Sobel test was used to explore mediating models.

Results: Results showed that internet use was negatively associated with DS among Chinese middle-aged and older adults. Among them, social needs (B=−0.770, p =0.041), and information reception (B=−1.067, p =0.007) were significantly related to DS in middle-aged and older adults. Only information reception (B=−3.161, p =0.031) was significantly related to DS among middle-aged and older adults with functional disability. Social isolation partially mediated the association between internet use and DS in middle-aged and older adults without functional disability, whereas it was fully mediated in middle-aged and older adults with functional disability.

Conclusion: This study indicates that when formulating health policies to promote the mental health of Chinese middle-aged and older adults, the use of the internet should not be overlooked.

KEYWORDS

internet use, depressive symptoms, functional disability, social isolation, middle-aged and older adults

1. Introduction

Depressive symptoms (DS), as a common psychiatric problem, are projected to become the major burden of disease worldwide by 2030 (1). DS are associated with increased mortality, functional disability, and a poor prognosis for many other diseases (2). The manifestation of DS in middle-aged and older adults has garnered extensive societal attention. Worldwide, the prevalence

of DS reaches its peak in individuals aged 55–74 years (1). In China, the combined prevalence of DS among middle-aged and older adults is significantly high, reaching up to 22% (3), with approximately 30% of men and 43% of women in the 45 and older age group experiencing such symptoms (4). The DS of middle-aged and older adults are usually a comprehensive result of physical, psychological, and social factors related to aging (5). Many late-life DS seem to be attributable to functional limitations caused by physical illness (6). Functional disability is considered to be the most important predictor of DS in middle-aged and older adults (7). There is growing evidence that activities of daily living/instrumental activities of daily living (ADL/IADL) disability is associated with DS (8). The prevalence of DS is higher among middle-aged and older Chinese with functional disability compared to those without such disability (8, 9). For each additional ADL/IADL disability type, the risk of DS in middle-aged and older adults increases by more than 2.6 times (7). People with functional disability may amplify DS by reducing perceived social support and psychological resources (10). Persistence of DS may lead to progressive deterioration of functional status (11). For middle-aged and older adults with functional disability, DS have long-term negative effects on their occupational roles, social adjustment, leisure activities, and family relationships (7). Not only does it reduce their psychosocial functioning and quality of life (12, 13), it can even lead to an increased risk of suicide (14). Therefore, it is critical to identify potentially modifiable factors of DS in middle-aged and older adults with functional disability. With the development of network information, the internet's functional versatility, immediacy, and accessibility offer the possibility to alleviate DS in middle-aged and older adults with functional disability.

Internet use is both a challenge and an opportunity for middle-aged and older adults with functional disability. With the increase of internet penetration rate, the scale of internet use among middle-aged and older adults is continuing to expand. There is growing concern about the potential adverse effects of age-related changes in physical functioning and the digital divide on internet use among middle-aged and older adults (15). Studies show that adults with ADL/IADL disability are significantly less likely to be online than other adults (54% vs. 81%) (16). Compared to other age groups, internet use rate is much lower in middle-aged and older groups where functional disability is most common (17). Due to the vulnerability of such groups in accessing and using communication, it may further exacerbate the inequality of information (18). Nevertheless, internet use has also brought benefits to such groups. The internet, as a comprehensive platform that integrates information, social interaction, and entertainment, can better meet the diverse needs of middle-aged and older adults. As stated by Hofer et al. (19), internet use can be seen as a valuable resource for older adults to manage loss, especially for those facing more mobility or activity limitations. Network informatization has contributed significantly to improving the life satisfaction of people with mobility disabilities (20), and may help increase internet use and use of virtual media as a means of meeting people (21). Related research has shown that analysis of online media can be an effective way to understand the health experiences of people with functional disability (22). Therefore, under the multiple backgrounds of

digitalization and aging, it is still necessary to pay attention to how the middle-aged and older groups benefit from the internet.

Internet penetration will have a certain degree of impact on mental health due to the effects of illness and functional disability in middle-aged and older adults. According to the internet compensation theory, internet use can help reduce DS by meeting people's unmet psychosocial needs in real life (23). Studies have reported a significant association between internet use and DS in middle-aged and older adults (24). However, current research findings are inconsistent. Most studies confirm that internet use as a simple, convenient, and low-cost means of social engagement can reduce DS in middle-aged and older adults (25, 26). But some studies have also found no association between internet use and DS (27). It may even lead to more serious health outcomes, such as increased depression (28), increased social isolation (29), etc. The emergence of the digital divide among the information-disadvantaged groups has further expanded social inequality and alienation from daily social life (30). Part of it can be explained as the negative psychological health consequences caused by the accompanying social exclusion, social isolation, and lack of social participation (31). Thus, there remains insufficient evidence to assess the relationship between internet use and DS in middle-aged and older adults, particularly among those with functional disability.

Internet use has been shown to have a significant impact on DS in middle-aged and older adults, yet few studies have explored the potential mediating mechanisms by which internet use affects DS. In studying the relationship between internet use and DS, some scholars have studied how internet use affects DS. They found that internet use improved DS by enhancing factors including social capital, such as social engagement, social support, and interpersonal relationships (32–34). The existing literature suggests that a range of social factors are associated with internet use and DS in middle-aged and older adults. It is worth noting that social isolation has always been considered a risk factor for poor physical and mental health (35, 36). Social isolation is more common among middle-aged and older adults due to factors such as living alone, chronic illness, and functional disability (37, 38). Numerous studies have shown that social isolation puts middle-aged and older adults at great risk of depression (36, 39). Internet use plays an important role in alleviating social isolation (40). The internet can reduce social isolation by expanding social networks or increasing the frequency of interactions with existing acquaintances (41). A study showed that social networks of sufficient size, quality, and frequency of interaction benefit middle-aged and older adults physically and mentally (42). Its role may be particularly evident when persons are unable to integrate into social groups due to mobility issues (43). Furthermore, according to the information processing model, the internet has long been considered a cultural tool that influences cognitive processes and an environmental stimulus that contributes to the formation of specific cognitive architectures (44). For socially isolated middle-aged and older adults, internet use may mitigate the negative effects of social isolation on a cognitive level. A recent study found that among socially isolated older adults, higher internet use was associated with lower levels of depression (45). This situation can be explained as the previous internet use habits of older adults may buffer the impact of social isolation on increased levels of depression. It can be seen that social isolation is a possible mediator between internet use and DS. Although previous studies have shown

an association between the internet, social isolation, and DS with each other (29, 36), few studies have discussed the potential role of social isolation in assessing the association between internet use and DS. It is unclear whether social isolation mediates the relationship between internet use and DS in middle-aged and older adults with functional disability.

Research remains divided on whether internet use has an impact on the health of middle-aged and older adults with functional disability. The purpose of the study is to explore the role of social isolation in the relationship between internet use and DS in Chinese middle-aged and older adults with functional disability. At the same time, the study will explore how they interact to reduce the risk of DS. The following research hypotheses are proposed: (1) Internet use is significantly associated with DS in middle-aged and older adults; (2) Social isolation mediates, to some extent, the relationship between internet use and DS in middle-aged and older adults with functional disability.

2. Methods

2.1. Data source and sample

This study is based on the data from Wave 4 of the 2018 China Health and Retirement Longitudinal Study (CHARLS). The nationally representative longitudinal survey began in 2011 and followed the sample in 2013, 2015, and 2018. The purpose of the survey is to investigate the health and economic adjustment of China's rapidly aging population, including demographic characteristics, socioeconomic status, family relationships, health status, and health care. A multi-stage probability sampling method was used to select the sample, with the final sample drawn from 150 counties in 28 provinces in China. The further detailed description of the CHARLS data can be found in the cohort profile (46).

The 2018 CHARLS data selected for the study is the most recent wave of data available, covering 19,816 respondents aged 45 years and older in 450 communities (villages) in China. Considering the needs and objectives of the study, a total of 7,955 participants, including 3,845 males and 4,110 females, were included after excluding respondents under 45 years of age (age < 45 or missing date: 261) and participants with missing key variables (internet use missing data: 22, social isolation missing data: 9460, DS missing data: 2118). All interviewees were required to sign informed consent. Ethics approval for the data collection in CHARLS was obtained from the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015).

2.2. Variables

2.2.1. Independent variable

Internet use was selected as the independent variable. In the CHARLS 2018 questionnaire, the following question was used to measure internet use, where respondents were asked to answer the question "In the past month, have you used the internet?" By answering "yes" or "no." We treated their responses as a dichotomous variable, recorded as "yes = 1" and "no = 0" (47). The types of functions used on the internet were also surveyed, with options including chat, watch news, watch videos, play games, financial management, and others. This study classifies chat as social needs, where middle-aged and older adults use the internet to keep in touch with their children, relatives, and friends. Watch news is information reception, where middle-aged and older adults use the internet to actively obtain information and integrate into society. Watch videos and play games are entertainment activities, which can enrich spiritual life. Financial management and others are the functions of daily life.

2.2.2. Dependent variable

Researchers used the Center for Epidemiologic Studies Depression Scale (CES-D-10) to assess the severity of individual DS. A total of 10 items on the CES-D-10 assessed participants' feelings during the previous week, such as worry, hope, fear, loneliness, unhappiness, attention deficits, and sleep disturbances. Respondents were asked to rate the frequency of each item by choosing one of four response options ranging from "0 = little or no time" to "3 = most or all of the time." The sum of the scores ranges from 0 to 30, with higher scores indicating greater severity of DS. In this study, respondents with CES-D-10 ≥ 10 were categorized as having DS, whereas respondents with CES-D-10 < 10 were categorized as not having DS (48).

2.2.3. Mediating variable

The four items were combined to form a score for social isolation (49). A score of 1 was assigned for each of the following: (1) Unmarried (never married, separated, divorced, widowed); (2) Having less than weekly contact with children (face-to-face, telephone, or email); (3) Living in a rural area, and (4) Not participating in any social activities in the past month (e.g., interacting with friends; playing chess or cards; participating in sports, social, or other clubs). Scores ranged from 0 to 4, with higher values indicating greater isolation. We categorized participants according to whether their scores were low (≤1) or high (≥2).

2.2.4. Control variables

Based on previous literature, we controlled for possible covariates associated with DS in CHARLS. The respondents' demographic information including gender, age (45–59, 60–69, and ≥ 70 years), education level (illiterate, elementary and middle school, high school and above), self-reported health status (good, not good), life satisfaction (very, fair, and poor), chronic disease status (no and yes), activities of daily living (as measured by the Katz Index of Independence in Activities of Daily Living), instrumental activities of daily living (as measured by Lawton's Instrumental Activities of Daily Living), smoking (current smoked, ever smoked, and never smoked), and drinking status (current drink, ever drink, and never drink).

2.3. Statistical analysis

SPSS 26.0 and SPSS PROCESS (50) were used for statistical analysis. First, chi-square tests were used to describe differences in the prevalence of DS across different levels within the entire sample. Then, the study used multiple linear regression to explore the relationship between internet use and DS in middle-aged and older adults with functional disability. Also, to test the social isolation mediating effect, a pass-through analysis was conducted in PROCESS in SPSS, and the significance of the social isolation mediating effect was assessed using the Sobel test and corrected for bias by bootstrapping (bootstrap sample size of 5,000). The mediating effect was considered significant

only when both the total and indirect effects were significant. Results are expressed as regression coefficients and their bootstrapped 95% confidence intervals (CI), with a significance level set at $p < 0.05$. The mediation analysis also controlled for all covariates.

3. Results

3.1. Participants characteristics

As shown in Table 1, a total of 7,955 participants were included in this study, of whom 1,001 (12.58%) used the internet, 3,379 (42.48%) had DS, and 4,808 (60.44%) were in high social isolation. When comparing characteristics with and without DS, the prevalence of depression was associated with age, gender, education level, chronic disease status, social isolation status, and internet use.

The incidence of DS in middle-aged groups is higher than that in other age groups. Male and literate middle-aged and older adults are less likely to have DS than women and illiterate participants. The prevalence of DS was higher among participants with chronic medical conditions. Middle-aged and older participants who did not use the internet and were highly socially isolated had higher levels of DS.

3.2. Correlations

The results of the correlation analysis are shown in Table 2. Internet use was negatively associated with DS and social isolation. DS were positively correlated with social isolation. The significant correlations between the study variables provided a good basis for the subsequent hypothesis and mediation tests.

TABLE 1 Characteristics of the sample by the percentage of depressive symptoms.

Variable, N (%)	Total (N =7,955)	Depressive symptoms		p-value
		Yes (N =3,379)	No (N =4,576)	
Demographic variables				
Age				0.325
45–59	3,179 (39.96)	1,318 (39.01)	1861 (40.67)	
60–69	2,671 (33.58)	1,151 (34.06)	1,520 (33.22)	
≥70	2,105 (26.46)	910 (26.93)	1,195 (26.11)	
Gender				<0.001
Male	3,845 (48.33)	1,278 (37.82)	2,567 (56.10)	
Female	4,110 (51.67)	2,101 (62.18)	2009 (43.90)	
Education level				<0.001
Illiterate	3,472 (43.65)	1807 (53.48)	1,665 (36.39)	
Elementary & Middle School	3,524 (44.30)	1,337 (39.57)	2,187 (47.79)	
High School and above	959 (12.05)	235 (6.95)	724 (15.82)	
Self-rated health				<0.001
Good	5,615 (70.58)	1,838 (54.39)	3,777 (82.54)	
Not good	2,340 (29.42)	1,541 (45.61)	799 (17.46)	
Life satisfaction				<0.001
Very	2,630 (33.06)	718 (21.25)	1,912 (41.78)	
Fair	4,273 (53.71)	1,802 (53.33)	2,471 (54.00)	
Poor	1,052 (13.23)	859 (25.42)	193 (4.22)	
Smoking status				<0.001
Current smoked	2,183 (27.44)	813 (24.06)	1,370 (29.94)	
Ever smoked	1,232 (15.49)	423 (12.52)	809 (17.68)	
Never smoked	4,540 (57.07)	2,143 (63.42)	2,397 (52.38)	
Drinking status				<0.001
Current drink	2,654 (33.36)	926 (27.41)	1728 (37.76)	
Ever drink	312 (3.92)	137 (4.05)	175 (3.83)	
Never drink	4,989 (62.72)	2,316 (68.54)	2,673 (58.41)	
Chronic conditions				<0.001
No	1,449 (18.22)	391 (11.57)	1,058 (23.12)	

(Continued)

TABLE 1 (Continued)

| Variable, N (%) | Total (N =7,955) | Depressive symptoms | | p-value |
		Yes (N =3,379)	No (N =4,576)	
Yes	6,506 (81.78)	2,988 (88.43)	3,518 (78.88)	
ADL disability				<0.001
No	7,290 (91.64)	2,983 (88.28)	4,307 (94.12)	
Yes	665 (8.36)	396 (11.72)	269 (5.88)	
IADL disability				<0.001
No	6,749 (84.84)	2,578 (76.29)	4,171 (91.15)	
Yes	1,206 (15.16)	801 (23.71)	405 (8.85)	
Social isolation status				<0.001
Low isolation	3,147 (39.56)	1,096 (32.44)	2051 (44.82)	
High isolation	4,808 (60.44)	2,283 (67.56)	2,525 (55.18)	
Internet use				<0.001
Yes	1,001 (12.58)	278 (8.23)	723 (15.80)	
No	6,954 (87.42)	3,101 (91.77)	3,853 (84.20)	
Types of internet usage functions				
Social needs	677 (8.5)	192 (5.68)	485 (10.60)	<0.001
Information reception	781 (9.8)	211 (6.24)	570 (12.46)	<0.001
Recreational activities	710 (8.9)	205 (6.07)	505 (11.04)	<0.001
Daily life	207 (2.6)	48 (1.42)	159 (3.47)	<0.001

ADL, activities of daily living; IADL, instrumental activities of daily living.

TABLE 2 Bivariate correlations between variables of interest.

Variables	1	2	3
1 Internet use	1		
2 Social isolation	−0.363***	1	
3 Depressive symptoms	−0.128***	0.166***	1

***$p < 0.001$.

3.3. The relationship between internet use and depressive symptoms

Table 3 shows the results of the multiple linear regression. As shown in Table 3, specific regression results are demonstrated by gradually putting in individual characteristic variables and social characteristic variables.

The regression results of Model 1 showed that internet use was significantly and negatively associated with DS in middle-aged and older adults. After adding the personal characteristics and social characteristics variables sequentially, the regression coefficients of internet use are $-0.993(p < 0.01)$, $-0.931(p < 0.01)$, and $-0.493(p < 0.05)$ shown in Model 2, Model 3, and Model 4, respectively, still showed a significant association with DS in middle-aged and older adults. The results of this study support the conclusion that internet use can reduce DS in middle-aged and older adults. In addition, Model 4 shows the results of the effects of other control variables on DS in middle-aged and older adults. The effect of internet use on DS in middle-aged and older adults

remained significant ($p < 0.05$). Regression results showed that gender, age, education level, self-rated health, life satisfaction, chronic disease status, ADL/IADL status, and social isolation were all associated with DS in middle-aged and older adults. Among them, females had higher levels of DS than males. The lower the level of education, the more severe the DS. The worse the self-rated health status and life satisfaction, the more pronounced the DS in middle-aged and older adults. The more severe the DS manifested in middle-aged and older adults with ADL/IADL disorders and high social isolation.

3.4. The relationship between the type of functioning based on internet use and depressive symptoms

As shown in Table 4, after controlling for age, gender, education level, and self-rated health confounding variables, social needs (B=−0.770, $p = 0.041$), and information reception (B=−1.067, $p = 0.007$) were negatively associated with DS in middle-aged and older adults. However, only Information reception (B=−3.161, $p = 0.031$) was significantly negatively associated with DS in middle-aged and older adults with functional disability.

3.5. Analysis of mediating effects

Mediating analysis was performed according to the presence or absence of ADL/IADL disabilities. The mediating effect of social

TABLE 3 Regression analysis of internet use and depressive symptoms in middle-aged and older adults.

Variable	Model 1	Model 2	Model 3	Model 4
Internet use	−2.559*** (0.225)	−0.993*** (0.206)	−0.931*** (0.205)	−0.493** (0.210)
Age (ref: ≥70)				
45–59		0.073 (0.165)	0.216 (0.168)	0.666*** (0.169)
60–69		0.088 (0.163)	0.093 (0.163)	0.374** (0.162)
Gender (ref: male)				
Female		1.731*** (0.132)	1.856*** (0.195)	1.834*** (0.193)
Educational attainment (ref: high school and above)				
Illiterate		2.483*** (0.224)	2.458*** (0.223)	2.075*** (0.224)
Elementary and middle school		1.134*** (0.210)	1.135*** (0.209)	0.984*** (0.208)
Self-rated health (ref: good)				
Not good		3.614*** (0.143)	3.401*** (0.146)	2.941*** (0.149)
Life satisfaction (ref: fair)				
Very		−2.461*** (0.140)	−2.425*** (0.139)	−2.431*** (0.138)
Poor		5.672*** (0.197)	5.627*** (0.196)	5.391*** (0.195)
Smoking status (ref: never smoked)				
Current smoked			0.555*** (0.198)	0.531*** (0.196)
Ever smoked			−0.127 (0.225)	−0.103 (0.223)
Drinking status (ref: never drink)				
Current drink			−0.221 (0.152)	−0.156 (0.150)
Ever drink			0.067 (0.331)	−0.034 (0.327)
Chronic conditions (ref: no)				
Yes			1.295*** (0.168)	1.292*** (0.167)
ADL disability (ref: no)				
Yes				0.666*** (0.236)
IADL disability (ref: no)				
Yes				1.792*** (0.194)
Social isolation status (ref: low isolation)				
High isolation				1.011*** (0.140)
F-value	128.929***	403.636***	266.980***	235.183***
R^2	0.016	0.314	0.320	0.335

**p < 0.05, ***p < 0.01. Values in brackets are standard errors.

isolation on internet use and DS in middle-aged and older adults is shown in Figures 1, 2. Adjusted for the following covariates: age, gender, al attainment, self-rated health, life satisfaction, smoking status, drinking status, and chronic conditions. As shown in Figure 1, social isolation fully mediates the relationship between internet use and DS in middle-aged and older adults with functional disability. As shown in Figure 2, social isolation partially mediates the relationship between internet use and DS in middle-aged and older adults with nonfunctional disability.

Table 5 lists the direct and indirect effects of internet use on DS in middle-aged and older adults under different ADL/IADL status, and the corresponding 95% confidence interval (CI). In conducting the mediation analysis, the following covariates were adjusted for age, gender, education level, self-rated health, life satisfaction, smoking status, alcohol consumption status, and chronic disease. Except for ADL/IADL disabilities, the direct effect was not significant, the other

CIs did not contain 0, which indicated that the paths in the mediation model were basically significant. The direct effect of internet use on depression among middle-aged and older participants with functional disability was attenuated by social isolation (i.e., indirect effect = −0.805, $p < 0.001$, total effect = −1.881, $p = 0.016$). Among middle-aged and older participants without functional disability, social isolation partially mediated the effect between internet use and DS (direct effect = −0.545, $p = 0.017$, indirect effect = −0.788, $p < 0.001$, total effect = −1.333, $p < 0.001$).

4. Discussion

This study examined the impact of internet use on psychosocial health outcomes among middle-aged and older adults in the context of digital convergence and global aging. The findings suggest that

TABLE 4 Regression results of the type of function based on internet use and depressive symptoms.

Variables	B	SE	t	p-value
All participants (N = 7,955)				
Social needs	−0.770	0.376	−2.047	0.041
Information reception	−1.067	0.394	−2.710	0.007
Recreational activities	0.259	0.405	0.641	0.522
Daily life	−0.854	0.461	−1.853	0.064
Constant term	6.577	0.207	31.744	<0.001
F-value	202.577			<0.001
R²	0.169			
ADL/IADL disabilities (N = 1,513)				
Social needs	2.046	1.516	1.350	0.177
Information reception	−3.161	1.468	−2.153	0.031
Recreational activities	−1.022	1.583	−0.645	0.519
Daily life	0.152	1.564	0.097	0.922
Constant term	7.711	0.572	13.491	<0.001
F-value	42.143			<0.001
R²	0.183			

SE, standard errors.

FIGURE 1
Statistical analysis of intermediary models (ADL/IADL disabilities) (***p <0.001).

FIGURE 2
Statistical analysis of intermediary models (without ADL/IADL disabilities) (*p <0.1, ***p <0.001).
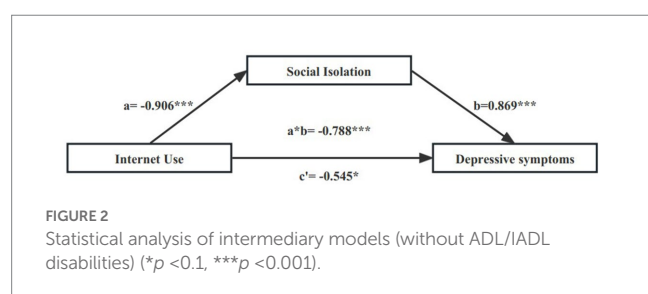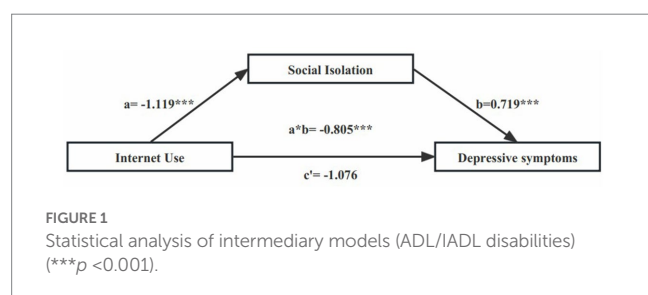
internet use is associated with DS. Providing interventions to improve social isolation may help directly or indirectly reduce the degree of risk for DS in middle-aged and older adults with functional disability.

The study results showed that internet use had a significant effect on reducing the risk of DS in middle-aged and older adults, which is consistent with previous studies (51). This study validates the internet compensation theory that internet use plays an important role in improving mental health outcomes. Middle-aged and older adults, especially those with functional disability, face barriers to accessing health services and participating fully in society (52). For this group, the internet, as an emerging technology, can provide health care,

entertainment, shopping information, etc., and enhance social connections. This may prompt middle-aged and older adults to adjust their psychological and social health barriers (53), thereby enhancing their sense of empowerment and independence (54), enabling them to have a better life experience and a higher level of health. Although the internet has the effect of improving DS. However, this study found that the number of middle-aged and older internet users is relatively limited. Middle-aged and older adults have the need to actively touch the internet, but there are still various obstacles in this process, such as the complexity of Apps, the inability to seek help, etc., (55). There is a lack of age-appropriate apps with simple interfaces and clear instructions to meet the demands of middle-aged and older adults. All these are not conducive to giving full play to the positive role of the internet. The relevant health departments should pay attention to cultivating the ability of this population to use the internet and increasing the internet penetration rate. Inevitably, internet use has negative effects. Considering the potential barriers to smartphone use (56) or the difficulty of indulging in the media environment due to the simple purpose of use and the short time of use (22), the impact of the internet on the mental health of middle-aged and older adults is moderate and positive.

Multifunctional internet use can potentially improve the DS of middle-aged and older adults. The study found that the social needs and information reception functions of internet use significantly reduced DS in middle-aged and older adults, with information reception being the most significant among functional disability groups. Research has shown that social media alone may not improve mental health in older adults (51). Touchscreen-based multifunction apps, including entertainment, transportation, social media-related, etc., may reduce the risk of DS in older adults (57). In contrast to the findings of Fan et al. (58) who hold that watch news had the least effect on depression levels in middle-aged and older adults. However, we discovered that information reception had the most significant effect on

TABLE 5 Mediating effects of social isolation between internet use and depressive symptoms in middle-aged and older adults with functional disabilities.

Model pathways	95% CI					
	Effect	Lower	Upper	SE	t	p-value
ADL/IADL disabilities (N = 1,513)						
Indirect effect	−0.805	−1.235	−0.406	0.221	−3.641	<0.001
Direct effect	−1.076	−2.654	0.502	0.805	−1.338	0.181
Total effect	−1.881	−3.414	−0.349	0.782	−2.407	0.016
Without ADL/IADL disability (N = 6,442)						
Indirect effect	−0.788	−0.945	−0.641	0.079	−9.984	<0.001
Direct effect	−0.545	−0.994	−0.096	0.229	−2.381	0.017
Total effect	−1.333	−1.762	−0.904	0.219	−6.088	<0.001

CI, confidence interval; SE, standard error.

depression levels in middle-aged and older adults. Internet information acquisition can promote middle-aged and older adults to timely understand external information and the latest social development trends, so the influence degree of entertainment and social interaction gradually decreases. For people with limited mobility, this is especially beneficial (59). The abundance of information and resources on the internet makes it more conducive than traditional media (60) to improve the social isolation of middle-aged and older adults with functional disability (61). Middle-aged and older adults with functional disability can obtain more news about medicine, technology, and health through the internet, which will increase their frequency of contact with the outside world and reconnect with the environment. This may compensate to some extent for the social isolation in reality and thus improve their DS.

Social isolation fully mediated the relationship between internet use and DS in Chinese middle-aged and older adults with functional disability and partially mediated the relationship in middle-aged and older adults without functional disability. This implies that the internet reduces the risk of DS by improving social isolation in middle-aged and older adults with functional disability, which is similar to previous research findings (62). Middle-aged and older adults with limited mobility are more likely to experience loneliness and social isolation (63), and their likelihood of mental health risk is greater. The internet, as a coping mechanism for health challenges in later life, can be particularly helpful in keeping middle-aged and older adults who have limited mobility due to health conditions socially connected. It can play an important role in alleviating mental illnesses such as depression by building strong social networks for distraction from social isolation and painful emotions and directly enhancing their sense of self-worth (64). Given the cultural traditions that emphasize the importance of family and social networks, the link between social ties and health may be more pronounced in the Chinese population (65). Our findings also suggest that Chinese middle-aged and older adults with higher levels of social isolation, such as functional disability, may benefit more from internet use and that targeted internet health education is a possible safeguard to prevent or reduce the risk of DS. Future research on the relationship between different categories of functional disability and internet use among

middle-aged and older adults needs to be more nuanced and detailed.

There are certain limitations of the study. First, the use of cross-sectional studies cannot monitor changes in mental health dynamics in middle-aged and older adults, and further longitudinal studies are needed to confirm this in the future to deepen the understanding of mental health. Second, DS in middle-aged and older adults are influenced by numerous factors. Further exploration of the different components of internet use on the health of middle-aged and older adults is needed to more clearly elucidate the potential mechanisms of internet use on mental health. Furthermore, participants' DS were based on self-report measures, which may be influenced by personal feelings at the time, and thus bias may affect the results.

5. Conclusion

Under the background of accelerating global aging and expanding the scale of the older population, speeding up the digital integration of older adults, and narrowing the digital divide for older adults are the new demands and practical contents of promoting active aging in the digital society. Our findings determined that the impact of internet use on the mental health status of middle-aged and older adults can be predicted by social isolation status. For middle-aged and older adults with functional disability, internet use is critical for enhancing social relationships and maintaining their mental health status. The findings of this study highlight the need to develop and implement strategies or policies that promote or popularize internet use to mitigate mental health disparities among older adults in an internet society. Further research into the experiences of people with functional disability could lead to a broader survey of health care and policy interventions to address the health needs that may exist in the current global health crisis.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession

number(s) can be found at: http://charls.pku.edu.cn/pages/data/2018-charls-wave4/zh-cn.html.

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The impact of learning engagement on the subjective well-being of disadvantaged older adults in China

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Due to social transformation, economic reform, and the advent of an aging society, the number of disadvantaged older adults in China is increasing. The living conditions of the disadvantaged older adult groups determine society's stability to a certain extent. How to make their lives happier in their old age, promote their subjective well-being, and realize the "enjoyment of the older adults" is of great practical significance in improving social civilization and building a harmonious society.This study uses questionnaires to obtain survey data from the lower counties of Ningbo City, Zhejiang Province, where there is a high concentration of older learners, and used SPSS 27.0 software to process the data. The results indicated the following: the subjective well-being of disadvantaged and non-disadvantaged older adults differed significantly; learning engagement had a significant effect on enhancing the subjective well-being of disadvantaged older adults, and all dimensions of learning engagement had a significant positive relationship with subjective well-being (SWB). Compared to non-disadvantaged older adults, learning engagement had a more significant contribution to the SWB of disadvantaged older adults.

KEYWORDS

disadvantaged groups, learning to engage, subjective well-being, quantitative studies, economic situation, empty nest

1. Introduction

By the end of 2021, there were 260 million individuals aged 60 and above, of which 190 million were aged 65 and above (1). It was predicted that China's older adult population will exceed 400 million in 2033 and reach a peak of 487 million in 2053, accounting for 34.9% of the total population (2), making China a country that is "old before it is rich and old before it is ready." The increasing aging population makes the issue of older adults a global and strategic social problem. As China's social and economic structure continues to adjust and transform, some older adults are disadvantaged in several aspects of social life due to institutional arrangements, redistribution of interests, and their physiological decline, consequently becoming vulnerable (3). Disadvantaged older adults' state of life determines society's stability to a certain extent. Consequently, how to make their lives happier in their old age, promote their subjective well-being, and achieve "a happy old age" has become one of the focuses of academic and social attention.

Subjective well-being (SWB) is an essential comprehensive psychological indicator reflecting the quality of an individual's life, which is a cognitive evaluation and emotional experience of an individual's life (4). Goal theory suggests that SWB stems from the satisfaction of needs, the achievement of goals, and the realization of self-worth in milestones, all of which reflect individuals' needs in life. Disadvantaged older adult groups can gain subjective identity through participation in learning activities, with self-concept and self-activity goals, allowing for their senior needs to be satisfied, thus realizing their self-worth and enhancing their SWB (5). Research on vulnerable older adult groups gradually received scholarly attention in recent years. This study takes the relationship between learning participation and SWB of disadvantaged older adults groups in China as the base point. It investigates the current situation of learning participation and SWB of disadvantaged and non-disadvantaged older adult groups and analyzes the differences in SWB between them and the influencing factors to provide reference experiences and educational countermeasures for improving the SWB of disadvantaged older adult groups. In this study, the disadvantaged older adult group is defined as those eligible for empty nesting and have a monthly income of less than 1,000 RMB, using residence status and economic level as measurement criteria.

2. Review of past studies

2.1. Research related to disadvantaged older adult groups

The term "disadvantaged group" was first mentioned in China by Premier Zhu Rongji at the Fifth Session of the Ninth National People's Congress in March 2002, and issues related to this group have subsequently received widespread attention from all sectors of society (6). Researchers in China and abroad generally believed that disadvantaged groups were the most oppressed and uncompetitive groups in society, as opposed to powerful or entitled groups. Disadvantaged groups are generally divided into two categories: physically and socially disadvantaged. The former is caused by unavoidable factors, while the latter is predominantly caused by institutional issues (7). While disadvantaged older adults belong to the former group, there is still no precise prescribed standard for the conceptual definition and classification of the disadvantaged older adult group. Kutek (8) argued that older adults who are socially disadvantaged due to certain barriers and lack economic and political resources could be called the vulnerable older adult group. Mu et al. (9) argued that older adults who live alone and are incapacitated to care for themselves are an important part of the disadvantaged population. Chen (10) showed that the characteristics of disadvantaged older adults include low economic security, lack of spiritual comfort, and insufficient social participation.

By comparing the overall situation of disadvantaged and non-disadvantaged groups in Anhui Province, Li et al. (11) found that disadvantaged groups experience more negative emotions due to the long-term lack of companionship and care from family, friends, or children, and their emotional needs are not met. Keliman et al. (12) found that disadvantaged older adult groups had poorer physical and mental health and were more likely to develop mental illnesses such as Alzheimer's. Drawing on data from the World Values Survey, Cao

found significant differences in SWB across social classes, with disadvantaged older adults of lower economic levels having the lowest levels of SWB, experiencing various difficulties in interacting with others, more commonly experiencing psychological disorders, and facing a higher risk of social isolation (13).

Additionally, Sun et al. (14) found that a significant proportion of vulnerable older adults subscribe to the view that participation in learning is an adolescent and childhood task. They believe that older adults are not suited to continue learning due to organic decline, neither considering the possibility of learning participation nor recognizing the unique significance of learning in later life. This hesitancy reflects this group's misconceptions and negative attitudes toward learning participation. Participation in learning activity courses still incur financial cost, which is undoubtedly a significant expense for the disadvantaged older adult group, as they are already less financially resilient. Therefore, the cost factor may also be one of the reasons why they give up learning.

Accordingly, Hypothesis 1 was proposed as follow.

> *Hypothesis 1*: Disadvantaged older adults have lower physical and mental health and well-being and non-participation in learning activities than non-disadvantaged older adults.

2.2. Study on the factors influencing the subjective well-being of disadvantaged older adult groups

Combining the results of domestic and international studies, the factors influencing the SWB of disadvantaged older adults can be divided into three main categories: self, family, and social. First, self-factors are mainly examined from the perspectives of gender, physical condition, and economic level. The quantitative results of Li et al. (15) showed that disadvantaged female older adults have significantly lower SWB than men due to their longer life expectancy and higher widowhood rate. A recent national study has demonstrated that health status is one of the significant factors affecting the subjective well-being of vulnerable older people (16). Disadvantaged older adults are more likely to experience anxiety and fear due to their health status, and physical well-being affects their mood to a greater extent than non-disadvantaged older adults (9). The economic level currently remains the most critical factor affecting the SWB of older people in China. Most disadvantaged older people have poor income status and lack livelihood security, leading to a significant lack of SWB (17). Second, family factors mainly refer to marital status. Related studies confirmed that the SWB of older adults with spouses is higher than those without spouses. Yetter (18) found that marital status has a significant effect on disadvantaged older male adults and that disadvantaged older male adults who live with their spouses are less likely to die unexpectedly and are more satisfied with their lives.

Additionally, Mui and Burnette (19) argued that older disadvantaged female adults could lose confidence in life and develop negative emotions such as loneliness and emptiness due to widowhood. Finally, social factors include external elements such as life support and environment. Meehan (20) pointed out that there is a positive correlation between social support and individuals' positive emotions; the more social support older adults receive, the

more secure their quality of life will be and the higher their SWB. Maintaining a high level of life satisfaction is maintaining solid relationships with family and friends, and the association between social interactions and SWB in older adults cannot be ignored (21). In addition, different social environments may also affect the SWB of older adults. Some studies have shown that rural areas have a more substantial negative impact on disadvantaged older adults' SWB than those living in urban areas due to poorer economic conditions and activity facilities, resulting in lower levels of social participation.

2.3. Study on the impact of learning participation on the subjective well-being of disadvantaged older adults

Throughout domestic and international studies, few have directly explored the relationship between learning participation and the SWB of disadvantaged older adults. Most studies have viewed physical and mental health, quality of life in old age, and social practice participation as perspectives to verify the influence of learning on SWB in old age. As stated in Erikson's self-development theory, individuals mainly face the developmental dilemmas of physical aging, role transformation, and self-transcendence in old age. These dilemmas are the main contributors affecting older adults' sense of achievement, value, and well-being.

Disadvantaged older adults' health is in crisis as various organs and functions of the body gradually deteriorate with age. Coupled with being financially disadvantaged and unable to afford physical care, it eventually leads to a decline in mental health, which reduces life satisfaction and happiness. The World Organization for Economic Cooperation and Development (WECD) has found that mental decline in older adults can be delayed through educational training, which through learning sustains brain power activation and promotes the active aging of individuals (22). A study by Gu and Wang (23) scientifically showed that appropriate geriatric learning could assist vulnerable older adult groups in preventing common diseases. Simultaneously, knowledge of relevant mental health is beneficial for rationally coping with and resolving stress and destructive emotions and maintaining a positive attitude toward life, thus reducing the risk of psychological depression in older adults. Feng et al. (24) argued that old age is a period of physiological decline entailing role changes and loss. Additionally, losing the original role leads to the vulnerable older adult group facing role conflict when retiring from the social production field. At the same time, the departure of children causes the loss of emotional communication and the original role support as parents in the family, which hinders the role adjustment after retirement. This change affects the acquisition of happiness to some extent. Shepherd (25) used the formula of L (speed of learning) > C (speed of change) to present the relationship between learning and social adjustment, pointing out that by adapting to new roles and social development, older adults need to acquire new wisdom and skills. The acquisition of new wisdom and skills can only be achieved through learning. Boulton-Lewis and Li (26) found that participation in various educational activities could help disadvantaged older adults build more effective interpersonal relationships and psychological support systems, consequently contributing to their emotional well-being by gaining more care and help.

Learning to participate is one of the most important ways to promote social participation among the disadvantaged older adult population, not only to slow down the decline of their intellectual abilities but also to assist them in adapting to new roles and consequently increasing their motivation to participate in society. Additionally, it can help maintain normal interpersonal relationships, strengthen interactions with other groups and society as well as emotional attachment, develop positive emotions and avoid negative emotions. Finally, learning to participate can help disadvantaged older adults obtain an enjoyable old age career and enhance SWB. Accordingly, Hypothesis 2 and Hypothesis 3 are proposed as follows:

> *Hypothesis 2*: Learning engagement effectively increases the subjective well-being of vulnerable older adults.

> *Hypothesis 3*: Learning engagement has a higher positive effect on the subjective well-being of disadvantaged older adults than non-disadvantaged older adults.

3. Materials and methods

3.1. Sample selection

To further reveal the influence mechanism of learning participation on the SWB of disadvantaged older adults, this study was conducted in 2022 using a questionnaire survey method with a random sample of older adult groups aged 50 and above who were involved in older adult learning in the lower districts and counties of Ningbo, Zhejiang Province, where the concentration of older adult learners was high. Random distribution of electronic questionnaires to the above older adult groups using educational institutions such as community colleges and adult schools (based on domicile) as a platform. The international standard for classifying the age of the older adult is 60 years old, and the relevant policies and regulations in China also stipulate that the older adult are citizens who have reached the age of 60 or above; some people think that the older adult are retired people who have reached the age of 55 and are no longer engaged in social work. In contrast, this study uses age chronology as the defining criterion. The first person to define older people in terms of age chronology was the Swedish scholar Sandbar, who used the age limit of 50 years to delineate older people. Based on the actual context of the study and the requirements for enrolment in senior schools, this study refers to older individuals as seniors who are 60 years of age or older for males and 50 years of age or older for females and who can normally participate in learning activities in senior education institutions. The inclusion criteria and study objectives were explained to all participants and consent for participation was obtained prior to the start of the study. A total of 2036 questionnaires were collected, and after the screening, 2007 valid questionnaires remained, the sample size was calculated using the empirical formula method: the valid questionnaire return rate was as high as 98.6%, the non-response rate was as low as 1.4% and the sample produced less bias, therefore, the data is sufficiently representative and valid. The final sample composition was 1,216 (60.6%) for the disadvantaged older adult

TABLE 1 Statistics of demographic variables (*n* = 2007).

	Disadvantage	Non-disadvantaged	Overall
Total individuals	1,216 (60.6%)	791 (39.4%)	2007
Age (in years)			
50–59	458 (22.8%)	490 (24.4%)	948 (47.2%)
60–69	541 (27.0%)	244 (12.1%)	785 (39.1%)
70–79	205 (10.2%)	57 (2.8%)	262 (13.1%)
over 80	12 (0.6%)	0 (0.0%)	12 (0.6%)
Gender			
Male	187 (9.3%)	77 (3.8%)	264 (13.2%)
Female	1,029 (51.3%)	714 (35.6%)	1743 (86.8%)
Marital Status			
Married	1,104 (55.0%)	723 (36.0%)	1827 (91.0%)
Single	112 (5.6%)	68 (3.4%)	180 (9.0%)
Monthly income			
Under ¥1,000	95 (4.7%)	0 (0.0%)	95 (4.7%)
¥1,000–¥2,000	282 (14.1%)	218 (10.9%)	500 (24.9%)
¥2,000–¥4,000	457 (22.8%)	328 (16.3%)	785 (39.1%)
Over ¥4,000	382 (19.0%)	245 (12.2%)	627 (31.2%)
Education level			
Less than junior middle school	119 (5.9%)	58 (2.9%)	177 (8.8%)
Junior high school	509 (25.4%)	327 (16.3%)	836 (41.7%)
High school(including technical secondary school and professional high school)	403 (20.1%)	294 (14.6%)	697 (34.7%)
Junior college	123 (6.1%)	80 (4.0%)	203 (10.1%)
College/Bachelor's degree or above	62 (3.1%)	32 (1.6%)	94 (4.7%)
Living conditions			
Living alone (empty nest)	128 (6.4%)	0 (0.0%)	128 (6.4%)
Living with partner only (empty nest)	1,056 (52.6%)	0 (0.0%)	1,056 (52.6%)
Living with children (non-empty nester)	11 (0.5%)	170 (8.5%)	181 (9.0%)
Living with a partner and children (non-empty nester)	21 (1.0%)	618 (30.8%)	639 (31.8%)
Living in a residential care facility (non-empty nest)	0 (0.0%)	3 (0.1%)	3 (0.1%)
Type of household registration			
Rural	411 (20.5%)	362 (18%)	773 (38.5%)
Town	805 (40.1%)	429 (21.4%)	1,234 (61.5%)

group and 791 (39.4%) for the non-disadvantaged older adult group (Table 1).

3.2. Variable definition and coding

This paper uses the Questionnaire on Older People's Participation in Older People's Education and Subjective Well-being as the basis of data research. The questionnaire includes three sections: basic information about older people, learning participation, and subjective well-being. The homogeneity reliability of the questionnaire was 0.91, and the coefficients of each dimension and the total scale were between 0.80 and 0.93. The combined validity of all the variables was greater than 0.7, the average variance extracted (AVE) was greater than 0.5, and the square root of AVE was greater than the correlation coefficient between the generic dimension and other dimensions. These results indicate that the total scale's reliability meets the study's requirements.

TABLE 2 Variable codes and explanations.

		Value	Variable Explanation
Age		1–4	1 = 50–59; 2 = 60–69; 3 = 70–79; 4 = over 80
Gender		1–2	1 = Male; 2 = Female
Marital Status		1–2	1 = Married; 2 = Single
Type of household registration		1–2	1 = Rural; 2 = Town
Living conditions		1–5	1 = Living alone (empty nest) 2 = Living with partner only (empty nest) 3 = Living with children (non-empty nester) 4 = Living with partner and children (non-empty nester) 5 = Living in a residential care facility (non-empty nester)
Monthly income		1–4	1 = Under ¥1,000; 2 = ¥1,000–¥2,000; 3 = ¥2,000–¥4,000; 4 = Over ¥4,000
Education level		1–5	1 = Less than junior middle school; 2 = Junior high school; 3 = High school (includes technical secondary school and professional high school); 4 = Junior college; 5 = College/Bachelor's degree or above
SWB	Physical and mental health experience	1–6	From 1 (strongly disagree) to 6 (strongly agree). The higher the score, the higher the subjective well-being of the older people.
	Adaptation satisfaction experience		
	Self-development experiences		
Older adult learning	Learning investment	1–6	From 1 (strongly disagree) to 6 (strongly agree). The higher the score, the higher the level of participation in learning by older people.
	Learning atmosphere		
	Learning experience		

The basic information about the older adults refers to demographic variables, including individual characteristics and household characteristics: individual characteristics include age, gender, education, monthly income, etc. The household characteristics variables are household registration, marital status, residence status, etc. Older people's participation in learning is the dependent variable in this paper and consists of three dimensions: older learners' commitment to learning, learning atmosphere, and learning experience. Thirteen questions were asked about participation in learning. After standardizing the above data, Cronbach's alpha for the explanatory variables was 0.854, indicating good overall reliability and statistical significance. The results of the validation factor analysis indicated a good model fit: $\chi2/df = 1.762$, CFI = 0.99, TLI = 0.986, GFI = 0.972, and RMSEA = 0.041, indicating good structural validity of the scale.

The dependent variable in this study is subjective well-being of the older adult. In the design of the scale, reference was made to the "Chinese Urban Residents' Subjective Well-being Scale (short version)," and on the basis of the original structure, dimensions and scoring method of this questionnaire, the formulation and content of some questions of the original questionnaire were adjusted accordingly, taking into account the field survey. The subjective well-being of older people in this study is categorized into three dimensions: physical and mental health experience, adaptation satisfaction experience and self-development experience, comprising a total of 10 items on a 6-point scale ranging from '1 - strongly disagree' to '6 - strongly agree', with higher scores indicating a higher level of subjective well-being.

After standardization, the reliability of the explanatory variables was tested, and Cronbach's alpha was 0.882, indicating good overall reliability. The results of the validation factor analysis indicated a good model fit: $\chi^2/df = 1.157$, CFI = 0.984, TLI = 0.997, GFI = 0.997, and MSEA = 0.019, indicating good construct validity of the scale. The specific coding and assignment criteria for the above demographic, explanatory, and explained variables are detailed in Table 2.

3.3. Data analyses

SPSS 27.0 was utilized for all analyses.

1) Descriptive statistics and variance tests were used to analyze the differences in demographic variables in the SWB and learning participation dimensions of disadvantaged older adults.
2) An independent sample t-test was conducted to determine whether there was a significant difference between the SWB and learning engagement dimensions of disadvantaged and non-disadvantaged older adults.
3) Correlation analysis was used to identify the relationship between learning engagement and the SWB of vulnerable older adults.
4) Based on the correlation analysis, a stratified regression method was used to examine the mechanism of the effect of learning participation on the SWB of the disadvantaged older adult group and to discover the specific differences in the effect of

TABLE 3 Descriptive statistics and difference test results of variables.

	SWB	Learning atmosphere	Learning Experience	Learning investment
Single	5.52 ± 0.78	5.52 ± 0.74	5.52 ± 0.76	3.80 ± 0.63
Married	5.44 ± 0.90	5.45 ± 0.89	5.47 ± 0.89	3.87 ± 0.70
t	1.07	1.00	0.75	−1.49
Male	5.25 ± 0.95	5.27 ± 0.89	5.27 ± 0.96	3.80 ± 0.66
Female	5.55 ± 0.76	5.55 ± 0.73	5.55 ± 0.74	3.80 ± 0.64
t	−4.82***	−4.78***	4.49***	−0.19
50-59	5.55 ± 0.74	5.57 ± 0.68	5.56 ± 0.71	3.70 ± 0.58
60–69	5.51 ± 0.79	5.51 ± 0.77	5.52 ± 0.78	3.85 ± 0.65
70–79	5.39 ± 0.88	5.39 ± 0.89	5.37 ± 0.89	4.04 ± 0.71
Over 80	4.14 ± 1.25	4.28 ± 1.35	4.07 ± 1.26	3.50 ± 0.82
F	15.22***	14.23***	18.44***	22.89***
Under ¥1,000	5.45 ± 0.96	5.41 ± 1.03	5.41 ± 1.00	3.45 ± 0.67
¥1,000–¥2,000	5.62 ± 0.70	5.58 ± 0.74	5.61 ± 0.69	3.65 ± 0.62
¥2,000–¥4,000	5.50 ± 0.79	5.51 ± 0.73	5.52 ± 0.76	3.78 ± 0.63
Over ¥4,000	5.44 ± 0.83	5.46 ± 0.76	5.44 ± 0.81	4.01 ± 0.61
F	4.86**	2.84*	5.08***	43.53***
Less than junior middle school	5.67 ± 0.74	5.63 ± 0.79	5.63 ± 0.80	3.61 ± 0.69
Junior high school	5.59 ± 0.72	5.58 ± 0.69	5.59 ± 0.69	3.72 ± 0.64
High school (includes technical secondary school and professional high school)	5.50 ± 0.76	5.50 ± 0.75	5.51 ± 0.76	3.89 ± 0.61
Junior college	5.25 ± 0.94	5.27 ± 0.87	5.23 ± 0.92	3.96 ± 0.63
College/Bachelor's degree or above	5.10 ± 1.08	5.25 ± 0.89	5.20 ± 1.00	3.94 ± 0.53
F	15.76***	11.11***	13.96***	14.78***
Living alone (empty nest)	5.38 ± 0.98	5.40 ± 0.95	5.38 ± 0.96	3.78 ± 0.70
Living with a partner only (empty nest)	5.48 ± 0.83	5.48 ± 0.79	5.49 ± 0.79	3.82 ± 0.64
Living with children (non-empty nester)	5.62 ± 0.68	5.57 ± 0.72	5.61 ± 0.66	3.88 ± 0.63
Living with a partner and children (non-empty nester)	5.55 ± 0.71	5.56 ± 0.66	5.54 ± 0.73	3.75 ± 0.62
Living in a residential care facility (non-empty nester)	6.00 ± 0.00	6.00 ± 0.00	6.00 ± 0.00	3.56 ± 0.77
F	3.02*	2.26	2.47*	2.08
Rural	5.62 ± 0.70	3.65 ± 0.60	5.60 ± 0.69	5.63 ± 0.67
Town	5.44 ± 0.84	3.90 ± 0.65	5.45 ± 0.79	5.44 ± 0.82
t	5.24***	−8.64***	4.56***	5.52***

*$p ≤ 0.05$.
**$p ≤ 0.01$.
***$p ≤ 0.001$.

4. Results

4.1. Descriptive statistical analysis and test of variance

The study data showed (Table 3) that in the SWB dimension, there were highly significant differences in the SWB of the older adult groups by gender, age, monthly income, education, and household registration. Among them, the happiness level of the female group was higher than that of the male group. Regarding the age dimension, the subjective happiness of the older adult group aged 80 and above was the lowest; regarding the monthly income dimension, the subjective happiness of the older adult group earning between 1,000 and 2,000 RMB was the highest; regarding the household registration factor, rural areas were higher than urban areas. Additionally, there were significant differences in SWB among older adult groups with different residence statuses, and the SWB of non-empty nesting older adult groups was significantly higher than that of empty nesting older adult groups. In comparison,

learning participation on enhancing the SWB of the disadvantaged and non-disadvantaged older adult groups.

TABLE 4 Results of independent samples t-test (*n* = 2007).

Variables		Disadvantage	Non-Disadvantage	*t*	*p*
		M(SD)	M(SD)		
Older adult Learning	Learning investment	3.81 (0.65)	3.97 (0.62)	0.90	0.37
	Learning atmosphere	5.48 (0.80)	5.55 (0.68)	−1.97	0.05
	Learning experience	5.49 (0.81)	5.55 (0.72)	−1.82	0.07
SWB	Physical and mental health experience	5.42 (0.91)	5.52 (0.77)	−2.59	0.01
	Self-development experiences	5.46 (0.88)	5.55 (0.77)	−2.23	0.02
	Adaptation to meet the experience	5.54 (0.80)	5.62 (0.67)	−2.23	0.03

TABLE 5 Correlation analysis of the dimensions of subjective well-being of learning participation among vulnerable older adults (*n* = 1,216).

	1	2	3	4	5	6	7
Learning atmosphere	1						
Learning experience	0.848**	1					
Learning investment	0.112**	0.111**	1				
Physical and mental health experiences	0.733**	0.812**	0.122**	1			
Self-development experiences	0.761**	0.854**	0.150**	0.921**	1		
Adaptation to meet the experience	0.785**	0.865**	0.143**	0.894**	0.932**	1	
SWB	0.781**	0.867**	0.142**	0.968**	0.979**	0.967**	1

*$p \leq 0.05$.
**$p \leq 0.01$.
***$p \leq 0.001$.

no significant difference was identified in the SWB of older adult groups with different marital statuses.

In each dimension of older adult learning participation, there were significant differences in the learning atmosphere, learning experience, and learning commitment among older adult groups with different education, age, monthly income, and household registration type. There were no significant differences in learning commitment among senior groups of different gender, and there were differences in learning experience among senior groups with varying residence statuses. Additionally, there were no significant differences in the learning atmosphere, learning experience, and learning commitment among older adults with different marital statuses.

4.2. Independent sample *t*-test analysis of learning engagement and subjective well-being of disadvantaged and non-disadvantaged older adults

To further clarify the differences between disadvantaged and non-disadvantaged older adult groups regarding learning participation and SWB, a t-test of independence was conducted on the sample data using SPSS software (Table 4). The study data showed significant differences between disadvantaged and non-disadvantaged older adult groups regarding the learning atmosphere. Additionally, regarding mean values, the disadvantaged older adult group obtained lower scores than the non-disadvantaged older adult group in the learning atmosphere and learning experience dimensions. Furthermore, there were significant differences between these two groups in all three dimensions of SWB, and the disadvantaged older adult group was not as good as the non-disadvantaged older adults group in all three dimensions. Overall, there were significant differences in learning engagement and SWB between the disadvantaged and non-disadvantaged older adult groups. The former group had lower physical and mental health and well-being and performed more negatively in learning activity participation. Consequently, research hypothesis 1 was verified.

4.3. Correlation analysis of learning participation and subjective well-being of disadvantaged older adults

Pearson correlation analysis was conducted (Table 5) to investigate the correlation between learning engagement and the SWB of disadvantaged older adults. The results showed that all dimensions of learning engagement of disadvantaged older adults were positively correlated with physical and mental health experience, self-development experience, adaptation satisfaction

experience, and overall SWB. The correlation was significant ($p < 0.01$). Among them, learning investment was lowly correlated with the SWB of disadvantaged older adults, the learning atmosphere was moderately correlated with the SWB of disadvantaged older adults, and learning experience was highly correlated with the SWB of disadvantaged older adults. The analysis indicated that the participation in learning activities of the disadvantaged older adult group could significantly enhance their SWB. Therefore, hypothesis 2 was verified.

4.4. Stratified regression analysis of the effect of learning engagement on the subjective well-being of disadvantaged and non-disadvantaged older adults

4.4.1. Multicollinearity test

This study used a hierarchical regression method to explore the effects of learning atmosphere, learning experience, and learning engagement on the SWB of disadvantaged and non-disadvantaged older adults. The problem of multicollinearity needed to be tested before conducting the regression analysis. Multicollinearity means that the high correlation between variables affects the analysis results. The condition for judging multicollinearity is that the variance inflation factor (VIF) is greater than 10.00 while the mean VIF is greater than 1.00. Although the mean VIF (1.67) in this study was slightly greater than 1.00, the VIF of all variables was less than 5.00, indicating no serious multicollinearity problem and that stratified regression could be conducted.

4.4.2. Stratified regression model construction

Based on the above descriptive statistical and correlation analyses, separate stratified regressions were conducted for disadvantaged and non-disadvantaged older adult groups. Model 1 only included learning variables (learning atmosphere, learning experience, and learning investment); model 2 added individual demographic characteristics factors (age, gender and education); and model 3 sequentially added household factors from demographic variables (marital status and household registration type, etc.) These models were chosen to more comprehensively reflect the impact of learning participation on the SWB of disadvantaged and non-disadvantaged older adult groups and its changing trend. The following multiple linear regression model was utilized, where Y referred to the dependent variable (subjective well-being) and X_1, X_2, … X_k referred to the independent variables (older adult learning participation and its factors):

$$Yi = \beta 0 + \beta 1X1 + \beta 2X3... + \beta iXi + \varepsilon \qquad (1)$$

Regression analysis of the total sample of older adults found that the standardized equations for the three multiple linear regressions for the full, disadvantaged, and non-disadvantaged samples were as follows:

$$Y\left(\text{full sample}\right) = 0.192 \times \text{learning atmosphere} + 0.714$$
$$\times \text{learning experience} + 0.030$$
$$\times \text{learning investment}$$

$$Y\left(\text{disadvantaged sample}\right) = 0.166 \times \text{learning atmosphere} + 0.755$$
$$\times \text{learning experience} + 0.056$$
$$\times \text{learning investment}$$

$$Y\left(\substack{\text{non} \\ \text{–disadvantaged sample}}\right) = \begin{array}{l} 0.255 \times \text{learning atmosphere} + 0.651 \\ \times \text{learning experience} + 0.044 \\ \times \text{learning investment} \end{array}$$

The results of model 1 indicated that learning atmosphere, learning experience, and learning investment all have a significant positive effect on the SWB of overall older adults ($F = 1926.256$, $p < 0.001$) with R-square = 0.743 (which explains 74.3% of the variance probability of SWB). Based on the comparison of the regression results of SWB of the disadvantaged and non-disadvantaged older adult group samples, the two influencing factors of learning investment and learning experience had higher positive effects on SWB in the disadvantaged older adult group than that in the non-disadvantaged older adult group. Only one factor, learning atmosphere, had higher positive effects on SWB in the non-disadvantaged older adult group than in the disadvantaged older adult group. In a comprehensive analysis, the positive effect of learning engagement on the SWB of the disadvantaged older adult group was higher than that of the non-disadvantaged older adult group.

To further test the hypothesis, the degree of influence of learning engagement on the overall SWB of the older adult groups increased with the addition of variables related to individual characteristics and family factors in models 2 and 3. In contrast, the degree of influence of the learning atmosphere and learning experience decreased but remained significantly positive. In the sample of the disadvantaged older adult group, it was shown that after including individual factors, the influence of learning investment on their SWB increased significantly. In contrast, the influence of the learning atmosphere and learning experience decreased. With the intervention of family factors, the influence of the learning atmosphere and learning investment increased, while the influence of the learning experience decreased. The regression results of the SWB of the non-disadvantaged older adults group showed that the effect of all dimensions of learning participation on their SWB decreased and that learning engagement had a negative effect on them after adding individual factors; after including family factors, the effect of the learning atmosphere and learning experience on their SWB increased, while the effect of learning investment decreased. Although the effect of learning engagement on SWB in disadvantaged and non-disadvantaged older adult groups changed by different degrees after adding individual characteristics and family factor variables, the positive effects of learning experience and learning investment on SWB in disadvantaged older adult groups remained higher than those in non-disadvantaged older adult groups.

The results showed that before and after adding individual and family factors, the positive effect of the learning atmosphere and learning experience on the SWB of both disadvantaged and non-disadvantaged older adult groups was more pronounced and more thoroughly explained their SWB. Additionally, the coefficients of learning experience and learning investment on the SWB of the disadvantaged older adult group were higher than those of the non-disadvantaged older adult group. Moreover, learning investment had a negative effect on the SWB of the non-disadvantaged older adult

TABLE 6 Regression results of the effect of learning engagement on subjective well-being of older adults (n = 2007).

	Full sample			Sample of disadvantaged groups			Sample of non-disadvantaged groups		
	Model 1	Model 1a	Model 1b	Model 2	Model 2a	Model 2b	Model 3	Model 3a	Model 3b
Learning atmosphere	0.192*** (8.928)	0.189*** (8.786)	0.188*** (8.756)	0.165*** (5.981)	0.162*** (5.907)	0.163*** (5.952)	0.225*** (6.526)	0.225*** (6.489)	0.224*** (6.463)
Learning experience	0.714*** (33.816)	0.707*** (33.434)	0.707*** (33.397)	0.755*** (27.520)	0.745*** (27.102)	0.742*** (26.947)	0.651*** (19.865)	0.649*** (19.665)	0.650*** (19.737)
Learning investment	0.030* (2.158)	0.041** (2.838)	0.042** (2.862)	0.056** (3.091)	0.072*** (3.843)	0.075*** (3.941)	−0.010*** (−0.472)	−0.011*** (−0.469)	−0.011*** (−0.486)
Age		−0.010 (−0.728)	−0.005 (−0.371)		−0.014 (−0.818)	−0.008 (−0.459)		0.014 (0.590)	0.013 (0.502)
Gender		0.031 (1.116)	0.037 (1.290)		0.023 (0.670)	0.029 (0.852)		0.029 (0.575)	0.032 (0.620)
Educational level		−0.034** (−3.469)	−0.034** (−3.212)		−0.053*** (−4.178)	−0.047** (−3.465)		−0.005 (−0.297)	−0.015 (−0.858)
Marital Status			−0.042 (−1.319)			−0.022 (−0.529)			−0.059 (−1.132)
Type of household registration			0.006 (−0.291)			−0.37 (−1.387)			0.043 (1.404)
N	2007	2007	2007	1,216	1,216	1,216	791	791	791
R2	0.743	0.745	0.745	0.761	0.764	0.764	0.706	0.705	0.705
F	1926.256***	971.458***	728.764***	1289.867***	656.941***	493.068***	632.849***	315.593***	237.429***

*$p \leq 0.05$.
**$p \leq 0.01$.
***$p \leq 0.001$.

group. The combined model 1, 1a, 1b; 2, 2a, 2b; 3, 3a, 3b analysis indicated that the positive effect of learning participation on the SWB of the disadvantaged older adult group was more pronounced. Therefore, hypothesis 3 was supported.

4.4.3. Robustness test

To further ensure the reliability of the findings obtained from the above hierarchical regression, this study adopted a model change approach to replace the used hierarchical regression model with an ordinary least squares (OLS) regression model, drawing on the robustness testing method conducted by Wu et al. (27). The results of the OLS regression model show that the positive effect of learning engagement on the subjective well-being of disadvantaged older people is more pronounced and is largely similar to the overall picture reported in Table 6. Therefore, the results of the stratified regression are robust and the findings are more reliable.

5. Research conclusion and discussion

5.1. Discussion

First, there were significant differences in SWB between disadvantaged and non-disadvantaged older adult groups, and disadvantaged older adult groups exhibited more negative behaviors in learning participation. In this study, the disadvantaged older adult group mainly referred to those who are empty nesters and have poor economic levels. Regarding this group, three aspects of disease medical care, life care, and mental health care are the main problems

they face (28). Most disadvantaged older adults lack their relatives' companionship and social support, have low life satisfaction, and are more lonely than other non-disadvantaged older adults (29). Regarding material and economic conditions, this group has low disposable income in their old age, and they need to rely on their children, relatives, and friends to support them in their living and financial affairs.

Regarding learning, most disadvantaged older adults lack self-confidence, believe that their learning ability is inferior to others, have a weak self-affirmation, and want to spend little or no money on learning during old age. The proportion of disadvantaged older adults in the state of "watching more and participating less" is as high as 91.6% (30). This study found that community courses are open to disadvantaged groups for free. However, the number of sessions is small; simultaneously, the scope of community courses is limited, and disadvantaged groups far from the community college may have to give up the training due to various reasons such as transportation and time (31). Due to the impact of modern technology, many urban older adult disadvantaged groups have a strong interest in computer, digital, network, communication, and other computer technology knowledge. In contrast, the current provision of older adult education content is mostly based on traditional courses such as literature, calligraphy, and cooking. For older adult groups, it is challenging to keep up with social development and changes in their learning interests. Therefore, the number of teaching courses offered, the radiation range, and the matching of teaching contents affect disadvantaged older adult groups' enthusiasm to participate in learning activities.

In addition, this study indicated that there are significant gender differences in SWB, with higher scores for older female adults. These

differences are related to the traditional Chinese family model of "male domination and female domination, "where Chinese women have taken on the role of family caregivers and are less socially engaged. When they enter the field of study in later life and engage in learning activities, the need to reconstruct their social circle and are more likely to gain emotional support by making new friends and are, consequently, more likely to have higher SWB by making new friends for emotional support (32). Compared to other age groups, those aged 80 years and older have the worst outcome in all three areas of SWB and learning engagement. Additionally, poor physical and mental health due to advanced age should be critically examined (33).

Second, learning engagement has a significant role in enhancing the SWB of the disadvantaged older adult group, and all dimensions of learning engagement have a significant positive relationship with SWB. Learning engagement includes three dimensions: learning time investment, monetary investment, and the number of courses for disadvantaged older adults. In defining returns to education, Schultz (34) pointed out that individuals' perceptions of well-being can be achieved through non-monetary returns such as self-efficacy, social capital, and the perceived social status of the educated. Monetary returns, such as course investments, are financially burdensome for disadvantaged older adults. However, once invested, they are more likely to cherish the hard-earned learning opportunities. In this way, they are motivated to recognize gradually the value of the learning content. After participating in educational activities, they are physically and mentally happy, and contribute to the harmonious development of family and social relationships (35). The measurement of the learning atmosphere element mainly involves the perception and evaluation of the teacher's teaching ability, and the degree of rapport between teacher and students. Social support theory, based on social connection, strongly argues for the correlation between the learning atmosphere and SWB. Through social connection, individuals can reduce psychological contingency reactions, relieve mental tension, and improve social adjustment. Learning experiences focus on perceptions of older learners' interest in learning, their initiative in learning, the degree of focus on learning, and the importance of learning. Cathie's research shows that adults' participation in lifelong learning positively impacts their physical and mental health and that disadvantaged older adults who focus on learning give less thought to what was once unpleasant, such as engaging in learning activities with explicit learning. Suppose they have a clear interest and need to learn. In that case, they will be motivated to overcome difficulties in the learning process and complete the learning activities, increasing their positive emotional experience and, consequently, their subjective well-being (36).

This study also found that monthly income influenced learning engagement, with older adults with a monthly income of $4,000 or more having the highest learning engagement. The lower the education level, the better the learning experience of older adults, most likely due to the lack of previous education, making them value the existing educational opportunities and the unique experience of the learning process (37). Since urban areas have better learning facilities and activities than rural areas and have increased access to learning activities, urban older adults have a better learning environment than rural areas (38).

Third, compared to the non-disadvantaged older adult group, learning engagement significantly contributes to the SWB of the disadvantaged older adult group. After controlling for the variables of individual factors (gender, age, monthly income, and education level) and family factors (household registration, marital status, and residence

status) in a stratified regression, the comparison revealed that the two dimensions of learning engagement, learning experience, and learning investment more thoroughly explained the SWB of the disadvantaged older adult group. First, regarding the learning experience, compared to non-disadvantaged older adults, disadvantaged individuals lack children's care and emotional comfort in their daily lives and thus have more pronounced characteristics of "empty nest syndrome" (39). The learning experience, as emotional and behavioral support, allows them to experience the friendliness and rapport of their instructors and peers, establish new social relationships, and alleviate negative emotions such as anxiety and loneliness by obtaining spiritual help. Therefore, in the reality that the "empty nest characteristic" is more serious, the disadvantaged older adult group has a higher positive effect on enhancing SWB than the non-disadvantaged older adult group.

Material and spiritual conditions are essential criteria for measuring SWB and life satisfaction. The poor economic foundation is another characteristic distinguishing the disadvantaged older adult group from the non-disadvantaged older adult group. When the former cannot change their material conditions to obtain life satisfaction, enriching their spiritual life is undoubtedly a critical way to enhance their SWB. Learning is also a significant spiritual food in an individual's life, in which they can rediscover their values and have new spiritual pursuits to enrich their lives (40). Therefore, based on the above, the disadvantaged older adult group focusing on learning activities will be more likely to experience the pleasure and happiness brought by learning activities. Second, on the learning engagement dimension, many disadvantaged older adults report having to take care of their children and grandchildren after retirement and having little extra time to engage in other learning activities.

On the contrary, the non-disadvantaged older adult group has more energy to focus on learning because they do not live with their children and have a clear understanding and definition of essential goals. Disadvantaged older adults entering retirement need a clear role to play. The influence of spiritual and cultural activities such as literary creation enables them to re-choose, define, and adapt to their new social roles and live their old age peacefully. As a result, their subjective sense of well-being will also be higher than that of non-disadvantaged older adult groups.

5.2. Limitations and future directions

Due to the limitations of disciplinary perspective and research design, some shortcomings still need to be addressed in this study. First, the study sample was concentrated in the lower counties of Ningbo city in Zhejiang province; the study needs more breadth and representativeness of the disadvantaged older adult groups nationwide. The sample could be expanded to extend the findings of this study to a larger scale by reaching out to a broader group of older individuals in rural and inland areas. Second, this study adopted a quantitative research method; while the SWB of the research topic has a complex psychological mechanism, questionnaires and other methods are more reflective of statistical results and symbolic characteristics. Therefore, an interview and narrative method will be considered a follow-up to interpret the research questions in more depth. Thirdly, in the age structure of the sample in this paper, the age group of 50–69 has the largest sample size, while the two age groups of 70–79, 80, and above have a relatively small sample size; therefore, the sample representativeness of these two age groups is slightly

under-represented, and subsequent consideration will be given to expanding the sample size by increasing the recruitment range or time of the sample in these age groups. Fourthly, this paper uses an online format to distribute the electronic questionnaire, which requires a certain level of digital literacy from the participants, and this may affect the structure of the sample. Therefore, in subsequent studies, offline questionnaires will be used as far as possible.

5.3. Concluding remark

The innovation of this paper is mainly reflected in the following aspects: first, the research object has unique characteristics. In November 2015, it could be seen, from the document "Education 2030 Framework for Action: Ensuring Inclusive, Equitable and Quality Education for All for Lifelong Learning" promulgated by UNESCO, that the living status of disadvantaged groups is generally paid international attention (41), disadvantaged older adult groups belong to the physiologically disadvantaged group, and the intensification of population aging requires more attention on disadvantaged older adult groups. Studying the current situation of disadvantaged older adult groups can help to improve their quality of life and survival and development capacity while guaranteeing that the disadvantaged older adult groups enjoy the fruits of social development. Thus, it is significant to promote the active participation of disadvantaged older individuals in social integration. Second, the research content is relatively new. Most previous studies focused on the health and survival of disadvantaged older adult groups and considered improving their quality of life through economic and material social support. However, few studies directly related learning participation to SWB to enrich their spiritual life in old age. According to the survey data, 69.9% of disadvantaged older adults strongly desire to learn (42). Therefore, this study examined the learning participation and SWB of disadvantaged older adults to draw society's attention to the learning of disadvantaged older adults and to provide a reference and theoretical basis for the relevant departments to formulate policies.

Data availability statement

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

Ethics statement

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

Author contributions

YL conceived the framework of the article and the research design, and wrote the entire manuscript. HS conducted the data analysis and participated in the design of the article framework and the implementation of the research process. YY and RZ designed the questionnaire and participated in the sample data collection. BB was responsible for the submission and revision of the article. LS managed and coordinated the planning and implementation of the research activities. 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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Identify travel and health factors influencing well-being of the older adults—a case study in China

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Objective: With the increase in aging populations worldwide, the travel well-being of the elders has gained attention. The objective of this study is to examine the nonlinear relationships between the well-being of the older people in China and factors associated with travel and health.

Method: Based on the data collected in China, combined embedded feature selection and decision tree built by Gini index were utilized to screen for influential factors and to determine the importance of the features selected. Tamhane's T2 was used to study the differences in the important factors among older people with different levels of travel well-being.

Results: This study found that the travel well-being of older adults depends mainly on accessibility to public places, such as schools and medical facilities, and the availability of bus services. Out of expectation, the most important influential factor of travel well-being of older people is the distance from home to high school. This is related to the traditional Chinese concept of education. In addition, it was found that the body mass index is more important than self-perceived health as an influence factor of travel well-being of the elders in China. Social skills are important factors too.

Conclusion: This study investigated various health-related and travel-related factors and their impacts on the travel well-being of older adults Chinese with the overall goal to improve the quality of life of the elders in China. The findings may provide a theoretical basis for the implementation of various transportation management and urban planning and design -related policies to improve the travel well-being of older adults in China.

1. Introduction

1.1. Backgrounds

China has the largest number of older people globally and has entered a period in which its population is aging rapidly. Not surprisingly, the aging level and aging growth rate significantly exceeds world averages. By 2030, China's population aged 60 and older is predicted to soar to 360 million, accounting for a quarter of China's total population. An aging population brings

about associated problems. For example, older people often have poor or declining physical health and are more likely to suffer from chronic diseases than younger people (1, 2). They also have more difficulty achieving a certain level of mobility than the general population. A key societal aspiration is to improve the travel well-being of older adults by analyzing the current status of their travel well-being and exploring the influential factors and mechanisms that underlie it.

Sociologists, economists, and psychologists have undertaken extensive efforts to determine travel well-being factors. Numerous studies have proven that health, education, employment, personality, and family relationships significantly affect the travel well-being of the elders. Yet, only in the last two decades have the effects of travel and transport systems on travel well-being begun to gain attention from researchers. These researchers have found that travel behavior, travel well-being, mobility, and transport service facilities can influence the travel well-being of the elders either directly or indirectly (3–8). Compared with other age groups, elder population has evident group characteristics regarding travel behavior and health status. Chronic disease is more prevalent among older adults who are usually not diagnosed and undertreated for their low awareness (9). Being moderately overweight causes less figure trouble to the older people, increasing their survival rate (10). Older people have special age-related medical needs, and their participation in social activities is often curtailed because of mobility restrictions. Facilities within walking distance may have a more significant impact on their travel well-being. Most older people are retired and have more free time than younger people. They are more likely to travel for optional activities, visit friends, to seek medical attention and go shopping. They relatively pay less attention to travel time and travel mode than younger people (11). Therefore, specialized research is necessary to understand travel-related factors that may influence the travel well-being of the elders.

Investigations into factors that affect travel well-being usually rely on statistical models, which include ordered logistic regression, bivariate probit models, ordinary least-squares regression, multiple linear regression, and structural equation models (7, 8, 12–17). The main shortcoming of linear regression and logistic regression models is that they can only find the linear relationship between independent variables and dependent variables and ignore the interaction between explanatory variables. In real life, travel well-being results from multiple factors that interact with each other. For example, transport systems can play an essential role in improving the health of the elders in terms of the older adults' mobility and access to medical facilities as well as social opportunities and events away from home. Active transport modes such as walking and cycling and walkable communities have potential health benefits for older persons. Obviously, statistical models are unsuitable for evaluating travel-related and health-related factors combined effects.

To solve this problem, researchers can perform the explicit nonlinear transformation of input features which machine learning algorithms good at. Machine learning algorithms often have a strong learning capability, making them suitable for use in various research fields. In this study, we used a decision tree to study the influencing factors of travel well-being of older people because a decision tree can achieve nonlinear segmentation of features, handle the multicollinearity of the feature well.[21]Furthermore, a decision tree can produce visual classification rules and provides strong interpretability. Most importantly, a decision tree can output the importance of features, thus making comparisons between variables more intuitive.

Based on Chinese data from the China Family Panel Studies (CFPS) that were conducted by the Institute of Social Science Survey (18), this study built a decision tree to study the nonlinear relationship between the travel well-being of elders Chinese and factors that relate to the dimensions of both transportation and health. In particular, we divided the older adults into five groups, which correspond to the five levels of travel well-being identified in the CFPS. We also used Tamhane's T2 to study the differences in essential factors among the five groups. The overall conclusions that can be drawn from this study provide a theoretical basis for implementing of various travel well-being-related policies.

The organization of the remainder of this paper is as follows. In Section 2, we review the literature for definitions of travel well-being and its influential factors and presents the motivation for this research and the contributions of this paper. Section 3 discuss the data and methodology used in this study. Section 4 presents the model results. In Section 5, we analyze the critical, influential factors and suggest policies for improving the travel well-being of the older people in China. The final section draws vital conclusions.

1.2. Literature review

Scholars have undertaken a great deal of work to define travel well-being and explore the factors that influence travel well-being. We reviewed the literature related to definitions and determinants of travel well-being.

1.2.1. Definitions of travel well-being

The term 'travel well-being' has taken on various subtle and different meanings over time. Philosophers first attempted to provide a clear conception of travel well-being 2000 years ago, which formed two theoretical camps: hedonic, purported by Epicurus, and eudaemonic, purported by Aristotle (19–21). The former regarded the most incredible pleasure as the source of travel well-being, while the latter proposed that 'travel well-being is good', which considers virtue and pleasure. Bradburn and Noll put forward the concept of 'life satisfaction', defined as constructing an estimator's standard and comparing the estimator's current life condition to an expected life condition (22). Andrew and Withey later used life satisfaction to measure travel well-being (23), which initiated their research into the cognitive model of travel well-being. Based on the cognitive model of travel well-being and hedonic travel well-being, other researchers proposed the concept of subjective well-being, which consists of three components: people's emotional responses, domain satisfactions, and global judgments of life satisfaction (24, 25). Researchers who study eudaemonic travel well-being believe that subjective well-being is just one part of travel well-being and that too much emphasis is placed on emotions. They argue that self-expression is another essential component of travel well-being whereby an individual devotes themselves to study or work and give full play to his/her potential to obtain the experience and pleasure of self-realization (21, 22, 26). These two perspectives, hedonic and eudaemonic, constantly integrate with and complement each other (27, 28). Travel well-being generally reflects people's eternal pursuit of a good life. In this work, because of the single-item question measuring travel well-being in the CFPS dataset, we refer to travel well-being as an overall evaluation of life-based on "intuitive, affective appraisal and cognitively guided evaluation" (20).

1.2.2. Research on travel well-being of older adults

In recent years, researchers have begun to pay more attention to the effects of transportation and travel on travel well-being, and research objectives gradually have been expanded to include older adult populations (4, 5, 7, 29, 30). However, the precise relationship between the travel well-being of older people and travel remains unclear in China because of the relative lack of research. Early studies universally focused on the impact of health-related factors on the travel well-being of the elders, with little attention paid to the impact of travel-related factors. Furthermore, the travel environment, customs, culture, and health status of the older adults in China are different from those in Western countries. Directly apply conclusions of studies conducted in Western countries to a Chinese context is problematic. In China, walking and public transport are the preferred travel modes for the elders (11). Car ownership does not seem important to them. In addition, in Chinese culture that embraces family travel well-being, the older people often take responsibility for taking care of grandchildren (31). This unique family division of labor may change influencing factors of the travel well-being of elders in China.

1.2.3. Determinants of travel well-being

1.2.3.1. Effects of demographic characteristics

With such specification of conceptualizations of travel well-being, empirical researchers began to investigate the determinants of travel well-being. Travel well-being is affected by personal characteristics and other factors that change with age, including material conditions, social and family relationships, and social roles. By categorizing 71 articles that focus on the socioeconomic status of older people, Read et al. found that elders of poor socioeconomic status are concerned about their poor health and well-being (31). Later research also noted that education level indirectly effects travel well-being (32, 33). Concerning to the older adults in China, illiterate adults report significantly lower levels of travel well-being than literate adults. In addition, the level of education further affects subjective well-being indirectly via levels of income and health (16). Blanchflower showed that married women who have received higher education have the highest levels of travel well-being (34).Social activities and participation (e.g., providing support to others and participating in volunteer activities) and visiting friends also have been found to boost travel well-being and improve the health of older people (13, 35).

1.2.3.2. Effects of travel-related factors

The current elders population (age 65+) is in better physical condition than previous generations, participate in more social activities, and has a greater need for travel (36).The movement of people to and within areas of activity where people can satisfy their recreational needs and enjoy events and public services is realized in transportation. Convenient transport systems can generate freedom and belonging to the broader community. Greater mobility can also increase older people's confidence to achieve specific goals and improve their well-being (8, 37). Researchers have found that accessibility to transport service facilities (railway stations, bus stops, being close to the city center or schools) has a positive impact on travel well-being (7, 8). People who live close to the city center tend to have positive emotions, due partly to convenient transport that can carry

them to shops or allow them to enjoy delivery services (38). Moreover, convenient transportation and a walkable community can improve people's attitudes toward health and travel (37, 39, 40). However, according to research and analysis of older adults in the United Kingdom, walking difficulties can have a negative effect on travel well-being of the elders (3).

Researchers have analyzed a variety of outdoor activities, the choice of modes of transport, and the impact of achievable mobility on the subjective well-being of older people. The results indicate that mobility and physical activity have the most significant impacts on subjective well-being (41, 42). In conjunction with the importance of mobility, maintaining contact with friends can improve the subjective well-being of older people (35). Therefore, the effects of travel-related factors are intertwined with social factors and health-related factors.

1.2.3.3. Effects of health-related factors

An inverted U-shaped curve between life satisfaction and age is evident during older adulthood. People's life satisfaction increases with age and peaks at around age 65 (43). Some studies have pointed out that it is not aging that alters the level of travel well-being, but rather other factors, such as declining health, related to age groups (2, 7, 44). For example, in aging, older adults often experience limited physical ability and deteriorating health that may contribute to widespread depression and lower spiritual well-being (44, 45). A survey of elders in the United States showed that poor physical health has a significant and direct impact on the subjective well-being of older people (7). For example, chronic diseases reduce the quality of life and thus negatively affect travel well-being (3). Furthermore, people who have a high body mass index (BMI) or chronic lung disease are more likely to be depressed than those who do not (46, 47). Furthermore, compared with their objectively determining health status, the self-evaluation of the health of older adults is closely related to their spiritual well-being (44). Research also reveals the inverse relationship whereby travel well-being influences the health of the elders, with higher levels of travel well-being leading to a reduction in depressive symptoms. Some researchers have suggested that subjective well-being should be incorporated into health evaluation systems and considered in the development of medical systems (48). In short, researchers have found links between travel well-being and health, which includes self-perceived health, mental health, and physical health, in older adults.

1.3. Motivation and contributions

In the above, we review the literature for definitions of travel well-being and its influential factors. Personal circumstances, travel-related, and health-related factors have been found to be directly or indirectly correlated with the travel well-being of older adults. While previous studies have examined the factors that influence travel well-being from either a health or transportation perspective, few have examined the relative importance of travel and health factors together on the overall travel well-being of older adults. Moreover, most studies have relied on statistical models to investigate these relationships, with little application of machine learning algorithms to explore nonlinear relationships. Additionally, research has primarily focused on Western countries where the primary mode of travel is by car, making it crucial to examine the specific factors influencing travel well-being among

older adults in China, given the country's complex transportation environment and differences in travel behaviors.

This study aims to address this gap by investigating the travel-related and health-related factors that influence the travel well-being of older adults in China. Given traditional cultural values, older adults in China may be more likely to engage in family-related activities rather than personal leisure activities, and their travel modes may differ from those in Western countries. To achieve this goal, we utilize non-Western data collected in China and employ machine learning algorithms to identify and assess the significance of variables. Furthermore, through the combination of kernel density distribution and Tamhane's T2, we provide targeted recommendations to enhance the travel well-being of different groups of older adults in China.

In summary, this study offers a unique contribution by investigating a rarely studied combination of travel-related and health-related factors that impact the travel well-being of older adults in China, using non-Western data and machine learning algorithms. It also takes into account the country's specific cultural and transportation context, providing targeted recommendations for improving the travel well-being of different groups of older adults.

2. Materials and methods

2.1. Dataset

The data used in this study were derived from the CFPS aimed at investigating the government benefits that Chinese residents receive and many other topics, including transportation, educational outcomes, family relationships and dynamics, and health. The CFPS sample covers 25 provinces, municipalities, and autonomous regions. The interviews were launched officially in 2010 and were conducted in rural and urban areas simultaneously. Due to the complexity of the Chinese social system, the CFPS launched multidimensional data collection efforts at three levels: community, household, and individual. The community-level data include the political environment, village/residence, infrastructure, population, resources, transportation, revenues, and expenditures. The household-level data include family structure and membership, living conditions, social interaction, income and expenditure, and asset status. The individual-level data include education level, income, marital status, and psychological and physical health status. The profound research value and quality of the CFPS have been well recognized and acknowledged by the academic community.

This article selected data from the CFPS survey in third-tier cities (no subway) and rural areas to ensure that the overall categories of travel modes are relatively similar. And this study focused on the CFPS survey year 2010 because the data for 2010 contain more information about travel well-being, transportation, and health than the other survey years. The survey conducted in 2010 was initiated in March and lasted 4 months. Although the survey period from March to June covers two seasons, the mild and comfortable weather during spring and early summer, along with a stable temperature range, did not result in any significant deviations that may have affected the survey results. Therefore, the season did not have any impact on the survey results. No surveys were conducted in the northwest quadrant because most of these areas are plateaus, with vast areas and sparse populations, making it too difficult to conduct surveys.

We screened the data for the elder's population aged 60 and above from the CFPS dataset and removed data records with missing values from the analysis. Furthermore, we removed records with unreasonable values (e.g., waiting for a bus for more than 70 min). The final sample was 3,820 participants between 60 and 109 years old ($M = 68.16$; $SD = 6.863$) of whom 54.74% were male and 45.26% were female.

The purpose of this study is to validate the effectiveness of data analysis methods. Considering the significant resource investment required for conducting comprehensive social surveys, university researchers are unable to perform such studies. Therefore, this study chose to use the authoritative CFPS dataset. This approach can be extended to current research on the travel well-being of older adults. The analysis method of this dataset has significant practical and theoretical significance for the development of care measures for the current older population (the older adult) in terms of their travel well-being.

2.2. Variables

The dependent variable in this study is travel well-being. Participants in the CFPS responded to the question 'How would you estimate your level of travel well-being?' on a scale of 1 to 5, with 1 indicating not happy at all and 5 indicating very happy. The reliability and validity of measuring travel well-being in single items are proven (48). The independent variables are travel-related factors and health-related factors.

Socio-demographic variables include gender, marital status, education level, income, personal assessment of social status [social status], and sociability; the latter corresponds to the question 'How well do you think you get along with other people?' These variables are the most common factors that influence travel well-being. We added two variables, area and region, because CFPS covered 25 regions and investigated elders in urban and rural areas. The geographic contexts and built environment of urban and rural areas of each city are pretty different. We specifically considered sociability to include social relationships and support that can mitigate loneliness and increase the travel well-being of older adults (49).

The travel-related factors can be divided into three categories: family travel information, public transport services, and accessibility to public places (schools, medical facilities, libraries, leisure facilities, shopping centers, etc.). Family travel information includes the most commonly used travel mode in daily life [travel mode] and private car ownership [ownership of car]. We combined bus and subway within 'public transport' unlike prior research studies that typically included five commute modes (walking, biking, driving, taking a bus, or taking a subway). Most of the cities in China did not have a subway in 2010; only 11 older adults (0.2%) in the sample had traveled by subway. We added two additional travel modes: electric bike and 'other'. Worth noting also is that, in rural China, somewhat unusual means of transport, such as donkey carts and tractors, are commonplace. Public transport services are reflected in terms of the distance to the nearest bus stop [distance to bus stop] and average waiting time at the bus stop [waiting time], referring to the time between passengers arriving at the bus stop and getting on the bus, which represent the coverage and convenience of public transport, respectively. Public places accessibility is reflected in the time it takes to reach the nearest medical facility by the fastest

transportation mode [time to the medical facility], distance from home to the nearest high school [distance to high school], and time to the nearest city/town commercial center using the respondent's daily travel mode [time to commercial center]. These variables are treated as continuous variables except travel mode and car ownership. Note that the distance to the nearest high school is a new and rarely considered indicator of travel well-being of the elders. We selected this factor because high school admissions in China require proximity to a high school and the older adults are often the grandchild's primary caregivers.

Like the travel-related factors, the health-related factors also can be divided into three categories: objective physical health, objective mental health, and self-perceived health. Objective physical health includes BMI and several physical health impairment indicators reflected in the following questions: 'Have you been ill in the past 2 weeks?' [sickness], 'Have you had any chronic diseases in the last 6 months?' [chronic diseases], and 'Have you been hospitalized in the past year'? Note that BMI is an important international standard to measure degrees of weight and health and is computed by dividing the height by the square of the body weight. BMI is divided into five ranges by Asian standards, representing underweight, normal weight,

overweight, and obese classes one and two. Mental health is measured by the frequency of the feeling that life is meaningless in the last month [meaningless], which is a question taken from the Center for Epidemiological Studies-Depression Scale (CES-D) (50). Self-perceived health is the subjective assessment of one's physical condition [self-perceived health].

Table 1 and Figures 1, 2 provides summary statistics for the travel well-being groups and the explanatory variables. The travel well-being values of the older people range from 1 to 5, with 1 indicating least happy and 5 indicating most happy. These five values correlate with this study's five 'travel well-being groups. Table 1 shows the three categories of the independent variables: basic demographic information about the individual, travel-related factors, and health-related factors. The table shows that the average Travel well-being value of the older adults is 3.95, which is close to 4, indicating that most elders tend to give relatively high scores for their travel well-being. The table also shows that only 9% of the older adults' own private cars. The average distance to a bus station is 848 meters, which is more than 500 meters; China has been trying to improve the coverage of bus stops so that they are located within a radius of 500

TABLE 1 Variable descriptions.

Variable	Description	Mean	SD
Travel well-being (groups)	1 = not at all happy, 2 = less happy, 3 = fairly happy, 4 = happy, 5 = very happy	3.96	0.971
Demographic characteristics			
Region	0–24 represents the codes of 25 survey regions	11.53	7.687
Area	0 = village, 1 = urban,	0.62	0.485
Gender	0 = male, 1 = female	0.45	0.498
Social status	1 = low, 2 = less high, 3 = normal, 4 = quite high, 5 = high	2.83	1.019
Sociability	1 = bad, 2 = not good, 3 = normal, 4 = quite good, 5 = good	4.07	0.834
Income	1 = bad, 2 = not good, 3 = normal, 4 = quite good, 5 = good	2.14	0.988
Education	1 = illiterate and semi-literate, 2 = primary school, 3 = middle school, 4 = high school, 5 = undergraduate and above	2.02	1.174
Marital status	1 = widowed, 2 = divorced, 3 = unmarried, 4 = married	3.43	1.163
Travel-related factors			
Travel mode	1 = walking, 2 = bicycle, 3 = electric bicycle, 4 = public transport, 5 = car, 6 = other	1.77	1.399
Ownership of car	0 = no, 1 = yes	0.09	0.291
Distance to bus stop	Continuous variable (m)	848.88	1119.089
Waiting time	Continuous variable (min)	17.76	14.589
Time to business center	Continuous variable (min)	22.27	18.154
Distance to high school	Continuous variable (km)	9.83	14.033
Time to medical facility	Continuous variable (min)	11.12	9.894
Health-related factors			
BMI	1 = [0, 18.5], 2 = [18.5, 24], 3 = [24, 27], 4 = [27, 30], 5 = [30, 50]	2.29	0.858
Sickness	0 = no, 1 = yes	0.31	0.464
Chronic diseases	0 = no, 1 = yes	0.25	0.434
Hospitalization	0 = no, 1 = yes	0.13	0.339
Feeling of meaninglessness	1 = never, 2 = seldom, 3 = sometimes, 4 = often, 5 = almost every day	1.31	0.702
Self-perceived health	1 = poor, 2 = less healthy, 3 = fair, 4 = good, 5 = excellent	3.88	1.092
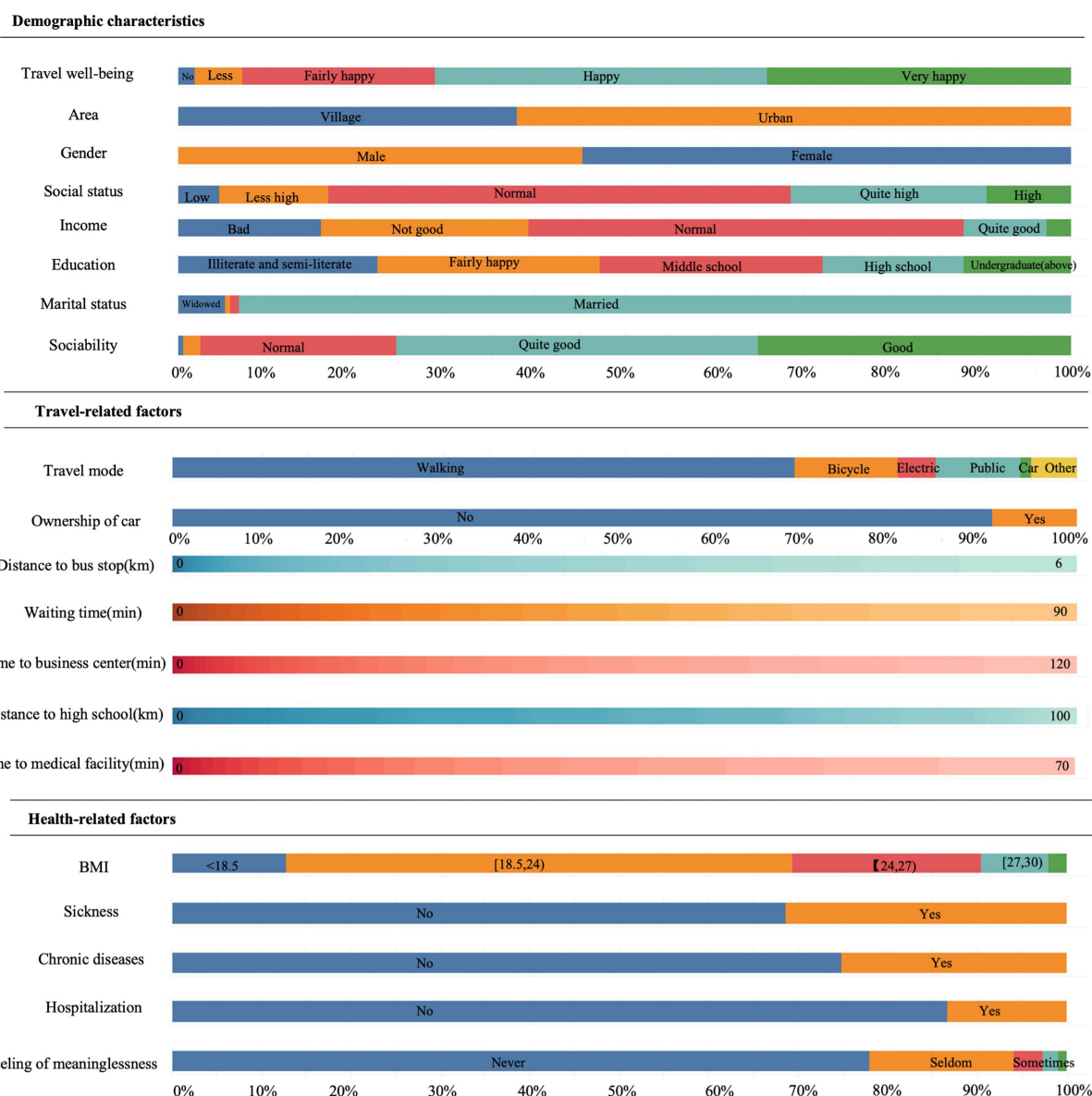
FIGURE 1
Share of discrete instances and range of continuous instances.

meters. The average waiting time for a bus is long, 17.76 min, which is more time than most people are willing to wait. Only 13% of seniors were in the hospital during the previous year. A quarter of the elder respondents had chronic diseases and the proportion (31%) of older people who had fallen ill in the past 2 weeks is relatively high. Most older adults never think that life is meaningless and feel in good health. The data also show high scores for sociability.

2.3. Screening factors that may influence travel well-being

We used embedded feature extraction, decision tree, and Tamhane's T2 to explore some of the variables that influence travel well-being. First, to select the appropriate indices, we used an embedded feature extraction method based on Extremely Randomized

Trees, a machine learning algorithm, to remove interfering factors and clarify the relationships between each factor and travel well-being. Then, we used a decision tree with the Gini index to obtain the degree of importance of the selected features and to determine each factor's degree of influence on travel well-being. Finally, to analyze the role of the crucial factors at the group level, we combined Tamhane's T2 with violin plots to investigate the differences in the critical factors among the five travel well-being groups.

Connections between things often can be seen more clearly by stripping away redundant factors and leaving only the key ones, which also can reduce difficulties associated with the analysis and computational burden of a model. Thus, features should be selected before further study. To this end, we used Select from Model, a feature extraction module built into Scikit-learn, an efficient machine learning tool, to extract features that contribute significantly to travel well-being. Select from model is a meta-transformer that can be used with

FIGURE 2
Mean and standard deviation of attributes.
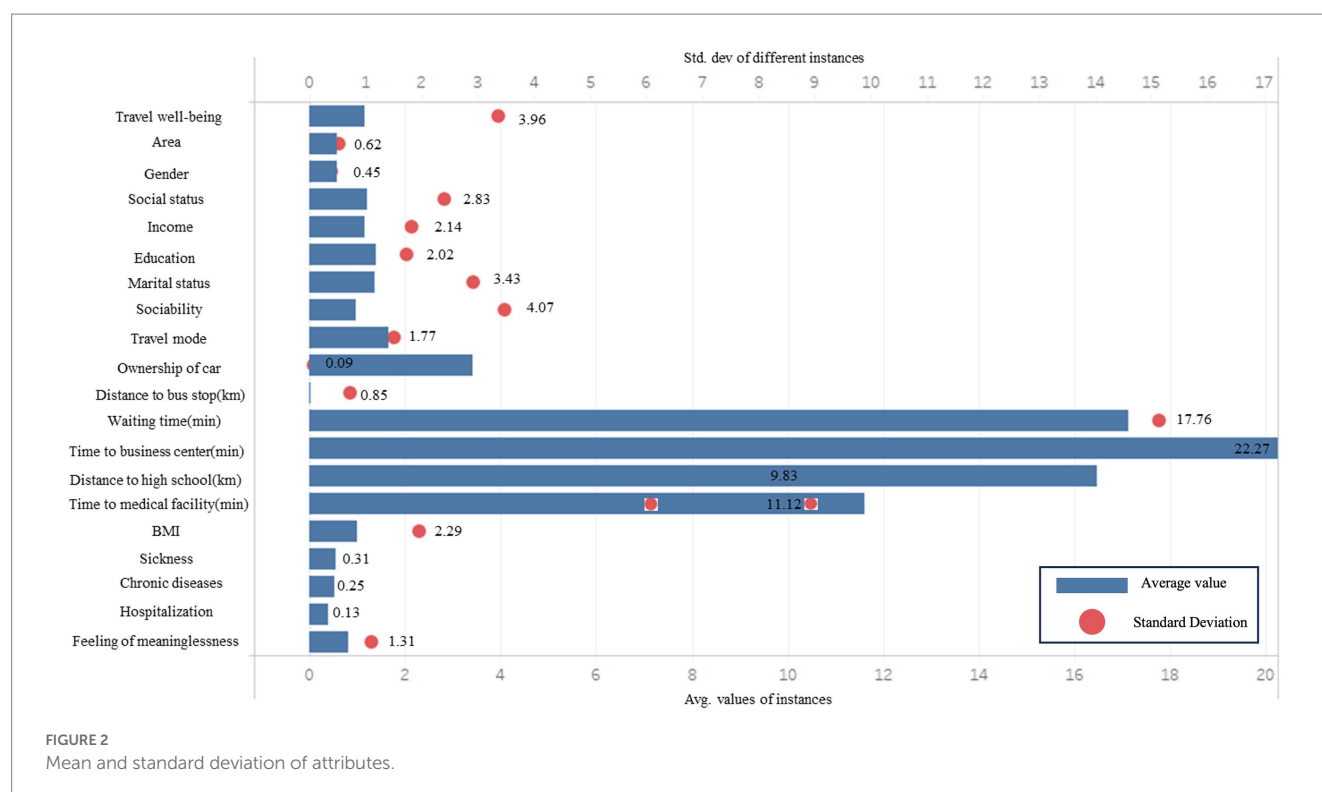
any estimator with feature coefficients or feature importance attributes after fitting. If the corresponding feature coefficients or feature importance values are below the threshold provided, these features are considered unimportant and removed. Such removal is an embedded method for feature selection. The intrinsic estimator we chose for this purpose is Extremely Randomized Trees, which can calculate the importance of features during learning (51).

Distance calculations are used frequently in machine learning applications and statistics. However, different dimensions may lead to unreasonable results in distance calculations that depend on features with large dimensions. Standardization can eliminate the effect of the dimensions of the feature on the results without changing the feature's original distribution. In this study, the standard deviations of the discrete variables' (see Table 1) generally were between 0 and 1. In contrast, the standard deviations of the continuous variables were significantly higher, with the most minor being 2.408 and the most prominent being 2323.64. Therefore, we used Z-score standardization before feature extraction to scale the original variables' data, thus making them conform to standard normal distributions ($\mu = 0$, $\sigma = 1$). The steps are as follows:

Step 1: Use Z-score standardization to scale the original continuous variables data.

Step 2: Use the Select from Model module to screen the variables and select Extremely Randomized Trees as the intrinsic estimator.

2.4. Acquiring the importance of features

Decision trees are standard decision support tools that have been used for factor analysis and are used in machine learning to make decisions based on a tree-like structure (52). Compared with other machine learning models, decision tree results are explainable and the

importance of features can be calculated. Quinlan's work can explain the principles that underlie decision trees (53, 54). In a tree structure, each internal node represents a test of a feature, each branch represents a test output, and each leaf node represents a category. The key to decision trees is to choose the best partition attributes. The three main ways to measure the pros and cons of attribute classification are information entropy, gain ratio, and Gini coefficient values. The importance calculation is based on these coefficients. The difference in the calculation results between the Gini index and information entropy is negligible although the Gini coefficient can be calculated much faster than information entropy. Thus, we used the Gini coefficient calculate the importance of the features in this study. Gini(D) represents the probability that two randomly selected samples belong to different categories from set D. Gini index (D, a) represents the probability after segmentation based on feature *a*. The lower the Gini index value, the greater the purity of the sample. Knowing the value of the feature with the highest Gini coefficient value, the uncertainty of the travel well-being score decreases. In other words, the feature that leads to the most significant reduction of the Gini index value of the sample is correlated closely with travel well-being and is the critical important feature. The sum of the importance of all the features is 1. The steps are as follows:

Step 1: Calculate the Gini index value for each feature, as shown in Equations 1 and 2.

$$Gini(D) = 1 - \sum_{k=1}^{|y|} p_k^2 j \tag{1}$$

$$Gini\_index(D,a) = \sum_{v=1}^{V} \frac{|D^v|}{|D|} Gini(D^v) \tag{2}$$

where p_k^2 is the proportion of the samples in category K in the current set $D(k = 1,2,3,\ldots, \mid y \mid)$; D^v is all the samples of D contained in the branch of the v node whose value for feature a is a^v; and a^v is the possible value of the feature a.

Step 2: Calculate the feature's importance. The importance of the feature is computed as the (normalized) total reduction of the Gini index value that is yielded by that feature.

2.5. Obtain intergroup differences of important factors

We used Tamhane's T2 to determine the intergroup differences in each variable and used violin plots to show the specific intergroup differences. Tamhane's T2 is a non-parametric multiple comparison tool that gives a test statistic using the t-distribution (55).Tamhane's T2 can be performed when the equal variance assumption is violated (56). The commonly used method for this purpose is the analysis of variance (ANOVA) that requires data to satisfy the homogeneity of variance. We found that our data failed to satisfy this requirement, so we used Tamhane's T2 instead.

A violin plot is used to show the distribution and probability density of multiple data groups. It combines the characteristics of a box plot and density, plot and is used mainly to show the distribution shape of the data. The width of the violin represents the density, and three dotted lines define the locations of the quartiles. A violin plot is similar to a box plot but is better for showing density; hence, we used violin plots in this study.

3. Results

We obtained the variables that can best predict travel well-being through feature selection and determined their importance using the decision tree. Figure 3 shows the 11 variables that contribute the most to predictions of travel well-being and thus were selected. The colors of the bars represent the categories of the variables. Green, blue, and red represents traffic-related factors, health-related factors, and demographic characteristics, respectively. The value indicates the importance of the variable to predict travel well-being. The higher the value, the greater the effect of the variable on travel well-being.

Figure 4 shows violin plots of travel-related and health-related factors density distributions. The width of violin represents the probability density of distribution.

Some socio-demographic variables, such as social status, sociability, region, and education level, contribute to the Travel well-being of older people. The most immense contribution comes from sociability, which is defined loosely as the ability to gather with and get along with other people. Also, the province where the elders live is an important factor that affects their travel well-being. It has been observed that the elders residing in more developed provinces tend to report higher levels of travel well-being compared to those living in less developed provinces. We also found that income is not an important determinant of Travel well-being. Educational background and social status also are linked to the travel well-being of older people, which is in line with other research findings (33). We found no gender differences in the travel well-being of the older adults.

As shown in Figure 4, when looking at the effects of public places accessibility, the most important feature is the distance from home to high school, which is also the most important factor of all the travel-related factors. Figure 3 (e) shows that the distance to high school value distribution for Group 5 (highest level of travel well-being) is significantly different from that of the other four travel well-being groups ($p < 0.01$). A high proportion of elders are 'very happy' to live within 5 km of a high school. Also, the time to a medical center matters more to the older adults than to the nearest commercial center. About to time to a medical facility, the distributions of Group 5 and Group 4 do not differ significantly, but the kernel density distributions of these two groups are significantly different from those of Group 2 and Group 3. Time to a commercial center has the same pattern across groups. The happy elders also have good access to health care, shopping centers, and leisure facilities. Concerning public transport services, the older people are concerned more about the distribution of bus stops than the waiting time at bus stops. The distance to a bus stop is nearly as important to them as the time to a medical facility. The distance to a bus stop for Group 5 is
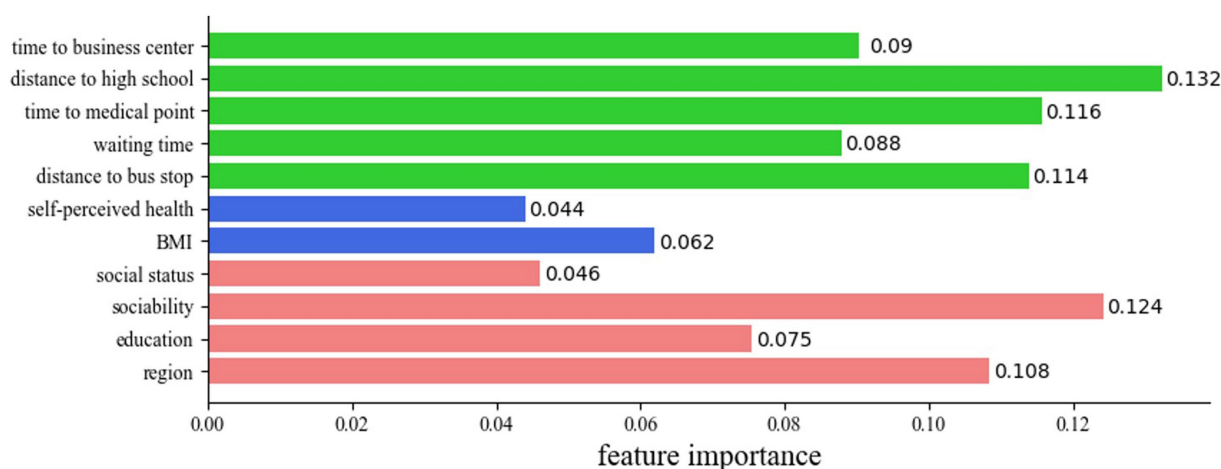
FIGURE 3
Importance values of explanatory variables.
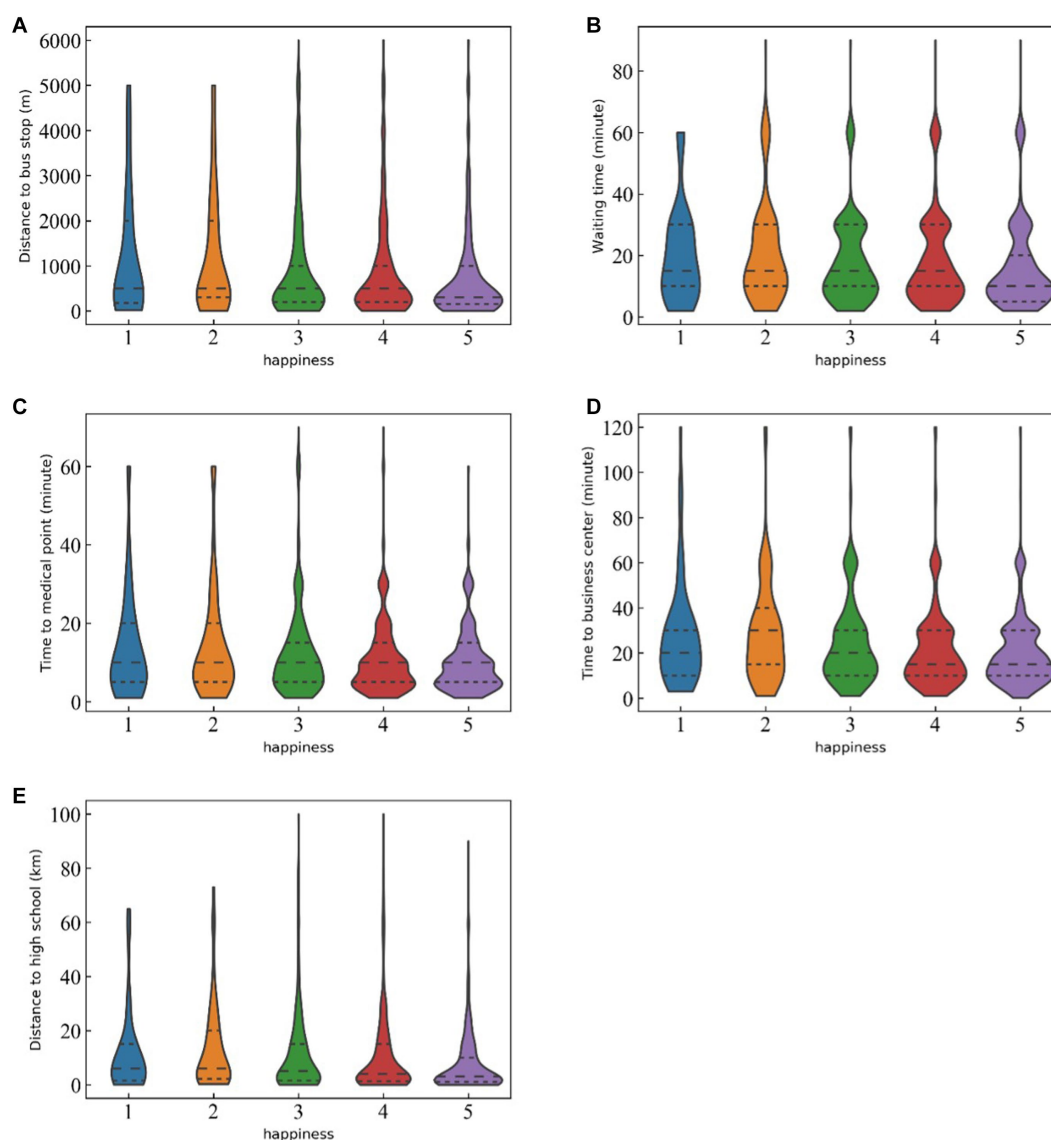
FIGURE 4
Density distributions of travel-related variables among groups.

significantly shorter than for the other travel well-being groups and is concentrated within 600 meters. Also, compared to the waiting time for other groups, the waiting time for Group 5 is significantly shorter, with 50% of the people waiting less than 10 min and 75% of the people waiting less than 20 min for a bus. Therefore, older people who can conveniently get to a bus stop or station that provides high departure frequency are more likely to report higher levels of travel well-being.

Similarly, Figure 5 shows the density distributions of the health-related factors. In terms of health-related factors, the results presented in Figure 5 (a) and (b) respectively indicate that self-perceived health, and BMI has important impacts on the travel well-being of older adults, and that BMI is more important than self-perceived health. As expected, and shown in Figure 5 (a), elders who perceive themselves to be in good health are more likely to report greater travel well-being. Figure 5 (b) shows that Group 5 in the normal BMI range is smaller than that of Group 4, but the proportion of older adults in the obese

range is higher. Mental health factors were meaningless in this study, and other objective health indicators, including sickness, chronic illness, and hospitalization, had no important effects on travel well-being.

4. Discussion

In this study, we examined the contributions of different variables, especially transportation mobility and accessibility-related factors, to the travel well-being of an elders Chinese population. The results help to identify travel-related and health-related factors that have the greatest potential for improving the travel well-being of older adults. Older people tend to report high levels of travel well-being, with a mean value of 3.95 (18). The reasons for this outcome may be that they have lower expectations of quality of life and are less able to change low conditions, so they are more likely to be forced to adapt to the
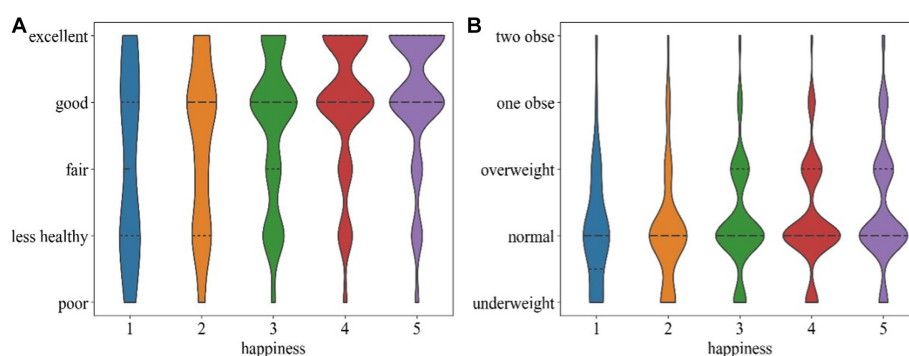
FIGURE 5
Density distributions of health-related variables between travel well-being groups: (a) self-perceived health and (b) BMI.

environment to maintain travel well-being compared to younger people (16, 27).

Older people's capacity to get along well with others strongly effects their travel well-being. This finding also corresponds to the results of Pinquart and Sorensen's study which show that quality social interactions can lead to higher levels of Travel well-being (35). The elders who have high emotional intelligence can participate in high-quality social activities to build their social network and gain support from the network. Other findings include that, except for being in a state of poverty, income has little effect on travel well-being (57). Also, as expected, elders with higher education and social status reported higher levels of travel well-being than people without such resources (58).

Transport and travel affect the travel well-being of older adults in many ways because transportation provides them with mobility and accessibility. This unexpected finding that the distance to a high school can be a travel well-being indicator seems to reflect that proximity to a high school benefits grandchildren of the elders, thus enhancing the travel well-being of grandparents. In China, living near a high school is one of the requirements for most high school admission. Children and grandchildren of older people living near schools are more likely to have access to an enjoyable learning atmosphere, good educational resources and make great achievements. The development of younger generations may have a more important impact on the elders travel well-being than hitherto thought. Moreover, the elders living near the high school can take care of the school-going grandchildren more conveniently, which relieves the burden on their children and let them enjoy the family travel well-being (37).

The time that it takes to travel to a medical center also is related to the travel well-being of the older people, and we found this factor to be more important than the time it takes to travel to a commercial/ shopping center. This finding is not surprising, because the older adults decreasing physical functioning means that proximity to medical facilities is more important to them than proximity to shopping and entertainment areas (2). Also, mobility in emergencies, especially when outbreaks of disease occur, provides psychological benefits to older people (59). Being able to reach healthcare facilities quickly allows older people to obtain timely medical treatment. In addition, although not as important as the ability to reach a medical center quickly, the time to the nearest city/town commercial center also affects the travel well-being of the elders where commercial centers, shopping and entertainment are concentrated. Corroborating this observation, previous studies have indicated the importance of

mixed land use and retail and services in the neighborhood of older adult people's dwellings (60). This underscores the substantial influence of easy access to a variety of facilities on the travel well-being of the older adult population.

The distance to a bus stop and the waiting time at a bus stop also affect the travel well-being of older people. The importance of the distance to a bus stop might be explained from two perspectives. First, compared to Western countries where most families have a private car, less than 10% of older adults own a car in China. When seniors need to travel a long distance, taking the bus is their first choice. Moreover, the government provides public transport subsidies for older adults so that the older people can take the bus or transfer to another bus for free. Therefore, having a bus stop near their residence is significant to the elders. By contrast, the farther away they live from a bus stop, the lower their travel well-being level associated with taking the bus (8). In a previous study conducted in Japan, it was found that living closer to public transportation was associated with higher levels of physical activity among older adults (61). Therefore, bus stops or stations that can be reached quickly and provide high departure frequency offer convenience for older adults and enhance their overall travel experience.

Unexpectedly, we found that the mode of travel does not have an important impact on older people's Travel well-being, which differs from the findings of other studies. In our findings, walking is the first choice for most elders (67.67%) for daily travel, followed by cycling (11.22%). The reason for this finding is that older people's family members are concerned about their safety and do not want them to ride bicycles or electric vehicles which are prone to accidents and require a high level of attention. Furthermore, considering the low levels of vehicle ownership in third-tier cities and rural areas, the travel options of older adults are limited. As results, unlike younger people, older people are forced to choose these two travel modes. Also, given the compromised physical condition of many older adults, they might not be able to enjoy walking or cycling. They might even feel that those modes of travel limit their ability to travel long distances. Zhu and Fan found that walking is associated with four negative emotions (62). Morris and Guerra's study indicates that utilitarian walking has no relationship with total well-being (63). Another reason is that the unbalanced structure of travel mode data reduces this factor's ability to predict travel well-being. This understanding aligns with the discussions in two World Health Organization documents - 'Global age-friendly cities: a guide' and 'Measuring the Age-Friendliness of Cities: a guide to using core

indicators' (60, 64). These documents underscore the importance of proximity to public transport and favorable walking conditions. They also advocate for a walking distance of less than 500 meters to public transport. Such recommendations dovetail with the principles of Transit-Oriented Development, which similarly emphasize the importance of short distances to public transport. Therefore, these documents and the present findings jointly illustrate the crucial role of easily accessible public transport in the well-being of older adult travelers."

Our finding that car ownership is not an important factor is consistent with Deka's research that likewise found that automobile ownership does not effect on travel well-being (25). In 2018, the motorization level in China stood at 173 motor vehicles per 1,000 inhabitants. In contrast, the European Union has a significantly higher average, with 567 passenger cars and 83 commercial vehicles and busses per 1,000 inhabitants. Therefore，the motorization level of China is very low compared to that of Western countries. According to the CFPS, only 9.18% of elders own a car and 1.13% of the older people's preferred travel mode is by car (including private cars and taxis). In China, only 1.98% of people over 60 have a driving license (11). Drivers over the age of 70 are required to undergo a yearly physical examination and are not allowed to drive if their physical condition is not up to standard. In addition, young people generally think it is dangerous for older people to drive and prevent them from driving even if the older adult has a valid driver's license. Therefore, car ownership has a very limited effect on improving the travel well-being of the elders in terms of their mobility.

Concerning health-related factors, this study found that BMI and self-perceived health have an important effect on the Travel well-being of older people; these results are supported by previous studies (10, 64–66). Linna et al. (67) found that a parabola curve exists between BMI and subjective well-being, and that subjective well-being is optimal in the overweight category. Being slightly overweight can reduce the mortality of older adults. However, obesity can lead to various diseases and decrease travel well-being (10). Self-perceived health is strongly associated with travel well-being among older adults. This finding confirms the results of previous studies that report a significant relationship between self-perceived health and psychological well-being among older adult (44).

Based on our analysis results, we propose several suggestions to improve the travel well-being of older adults in China. First, sociability is the most important personal factor that impacts travel well-being, which indicates that targeted transportation policies may result in the increased travel well-being of people who currently are severely restricted from maintaining social support networks because of problems associated with the transport system. Previous Studies found that some common barriers that older people face when traveling, such as lack of knowledge, physical limitations, lack of social support and negative beliefs of fear (68, 69). Therefore, a barrier-free travel environment is essential for older people to get out of the house and socializes. Second, improving the service level of public transport should be a government priority. Bus networks, stations, and stops should be planned and located so that the elders can walk to a convenient bus stop or station. Third, policy makers should pay more attention to unhappy people because the needs of those who are unhappy are more urgent than for those who are happy. The data show older adults who are unhappy take a longer time to the nearest medical facility than those who are fairly happy. Therefore, we propose

combining transportation planning and land use, synchronizing medical resources and medical staff, setting up medical facilities in every township and community, and ensuring convenient transportation channels to medical facilities (70). Lastly, a reasonable school admissions policy (based on comprehensive test score rather than the school district of residence) may improve the travel well-being of the older people.

5. Conclusion

Conducting empirical research and examining how travel and health influence the travel well-being of the elders are necessary and important across various contexts. For social equity, governmental and institutional policies should be tilted toward those who need help most urgently. To ensure that policies serve to improve the travel well-being of older adults Chinese with low levels of travel well-being, the gap between them and the older people who feel happy needs to be understood. Given the rapid increase in China's aging population, the factors influencing the travel well-being of elders Chinese are important considerations and worthy of study. This study investigated various health-related and travel-related factors and their impacts on the travel well-being of older adults Chinese with the overall goal to improve the quality of life of the elders in China.

This study aimed to investigate the contributions of travel and health-related factors to the travel well-being of older adults in China. We found that sociability and social connections are the most important personal attributes affecting travel well-being, while income does not have a significant impact.

Regarding accessibility to public places and other travel-related factors, the distance to the nearest high school was found to be the most important determinant of travel well-being for older people. This discovery is a new and interesting one that merits additional qualitative research to understand why proximity to school may have a significant impact on the travel well-being of older adults Chinese. We also found that the time to reach a medical facility is more important to elders Chinese than the time to a commercial center. Both the distance to a bus stop and the waiting time at a bus stop are important factors for travel well-being, and that the distance is more important than the waiting time. From the health-related perspective, BMI levels and self-perceptions of health have an important effect on the travel well-being of older adults.

Surprisingly, travel mode did not significantly influence travel well-being. The reason for this finding is that older people's family members are concerned about their safety and do not want them to ride bicycles or electric vehicles which are prone to accidents and require a high level of attention. Furthermore, considering the low levels of vehicle ownership in third-tier cities and rural areas, the travel options of older adults are limited.

This study has limitations. Limited by the CFPS dataset, the travel well-being dimension in this paper is relatively singular. In addition, the CFPS sample data cover 25 provinces/cities/autonomous regions that have substantial differences among them. This paper does not consider the influences of locational factors on the travel well-being of the elders. Additional research that entails a detailed survey of the travel well-being of the older people in specific regions may be useful. It can help people better understand the specificities of the populations of certain provinces, and can indicate the importance of

methodological application in other sociocultural contexts, of developing countries.

Few studies have examined the combined effects of travel and health on people's travel well-being, and the relationships remain ambiguous. Using a large sample of Chinese older people, we were able to explore the influential factors of travel well-being among health and travel. Ways to maintain older adults travel well-being by improving their health and travel should be analyzed comprehensively. While this study has limitations, the findings provide evidence for associations among various factors and put forward policy changes and new questions for further research. As China's aging population continues to grow, it is crucial to understand the factors influencing the travel well-being of older adults and develop policies that aim to improve their quality of life. To improve the travel well-being of older adults in China, policymakers should focus on developing a barrier-free travel environment that allows elders to socialize and access public transport conveniently. Additionally, bus networks, stations, and stops should be planned and located in a way that facilitates access for older adults. It is also essential to improve the synchronization of medical resources and medical staff to provide timely medical treatment to the elders, especially those who are unhappy.

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

SC and YM: funding acquisition, supervision, writing-reviewing and editing, and critical revision. YZ: conceptualization, methodology, data curation, writing-original draft preparation, and writing-reviewing and editing. QZ, HM, and MZ: conceptualization and methodology. 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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Association between chronic diseases and depression in the middle-aged and older adult Chinese population—a seven-year follow-up study based on CHARLS

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Background: With the aging of the Chinese population, the prevalence of depression and chronic diseases is continually growing among middle-aged and older adult people. This study aimed to investigate the association between chronic diseases and depression in this population.

Methods: Data from the China Health and Retirement Longitudinal Study (CHARLS) 2011–2018 longitudinal survey, a 7-years follow-up of 7,163 participants over 45 years old, with no depression at baseline (2011). The chronic disease status in our study was based on the self-report of the participants, and depression was defined by the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10). The relationship between baseline chronic disease and depression was assessed by the Kaplan–Meier method and Cox proportional hazards regression models.

Results: After 7-years follow-up, 41.2% (2,951/7163, 95% CI:40.1, 42.3%) of the participants reported depression. The analysis showed that participants with chronic diseases at baseline had a higher risk of depression and that such risk increased significantly with the number of chronic diseases suffered (1 chronic disease: $HR = 1.197$; 2 chronic diseases: $HR = 1.310$; 3 and more chronic diseases: $HR = 1.397$). Diabetes or high blood sugar ($HR = 1.185$), kidney disease ($HR = 1.252$), stomach or other digestive diseases ($HR = 1.128$), and arthritis or rheumatism ($HR = 1.221$) all significantly increased the risk of depression in middle-aged and older adult Chinese.

Conclusion: The present study found that suffering from different degrees of chronic diseases increased the risk of depression in middle-aged and older adult people, and these findings may benefit preventing depression and improving the quality of mental health in this group.

KEYWORDS

depression, aging, chronic disease, Chinese, mental health

1. Introduction

Aging is one of the most serious public health problems in China, and the old-age population in China is greater than the combined older adult populations of all the European countries (1). As of 2020, China has more than 264 million people over 60 years old, accounting for 18.7% of the country's population, and the average life expectancy has increased from 55.8 years in 1953 to 77.9 years in 2020 (2). Age-related health problems are one of the most severe consequences of population aging, such as chronic diseases in middle-aged and older adult people. Chronic diseases are socially harmful and may impose an enormous psychological and economic burden on patients and their families (3). It has been reported that chronic diseases have become the most significant health problem for the Chinese population and are the most prominent factor leading to the years lived with disability (YLD) (4). As the aging process accelerates, the prevalence of chronic diseases among the older adult population continues to increase (5). An epidemiological study of Chinese older adults found that 75.8% suffered from at least one chronic disease (6), and the risk of suffering two or more chronic diseases at the same time increases significantly with aging (7, 8).

Depression is a serious mental illness that causes abnormal moods, insomnia, loss of interest in life, and suicidal tendencies. It is estimated that more than one million people worldwide commit suicide yearly due to depression (9, 10). In recent years, the number of people with depression has been climbing. In 2017, the number of people with depression worldwide reached 258 million, of which in China exceeded 56 million (21.3%) (10, 11). The World Health Organization (WHO) predicts that depression will be the most burdensome disease in the world by 2030 (12). The middle-aged and older adult population is a high-risk population for depression, and the prevalence of depression increases with age. The accumulation of factors such as illness and loss of family and friends may exacerbate their emotional distress, leading to a greater susceptibility to negative emotions such as anxiety and depression, and some previous studies have found that the prevalence of depression in the middle-aged and older adult population in China is about 17.4 to 46.15% (13–16).

Some studies have shown that chronic diseases are strongly associated with depression (14, 15), including diabetes (17–19), chronic liver disease (20), kidney disease (21), cancer (22), stroke (23), and chronic obstructive pulmonary disease (COPD) (24), and as the number of chronic diseases increases, the patients have more severe mental disorders and a significantly increased the risk of depression (9, 25). In addition, several sociodemographic factors, as well as lifestyle factors such as age, education, BMI, marital status, economic status, social activities, nighttime sleep duration, and smoking or alcohol consumption, have also been shown to have a possible association with the development of depression (9, 26, 27), and there may exist some interaction effects between these factors. Therefore, exploring the risk factors for depression in middle-aged and older adult people and their interaction effects, as well as the relationship between depression and chronic diseases is significant for preventing and treating depression. Several previous studies used the CHARLS database to investigate the association between chronic diseases and depression in the Chinese middle-aged and older adult population, and they discovered a significant association between chronic diseases and depression, as well as that populations with multiple chronic diseases were at higher risk for depression (9, 15, 27–30).

However, because the majority of these studies are cross-sectional, causal conclusions about the association between chronic illnesses and depression cannot be drawn (15, 28–30). Previous cohort studies with short follow-up did not evaluate the most recent available data from CHARLS, and the study conclusions were out of date (9, 27). Furthermore, depression develops slowly, and insufficient follow-up time may result in an inaccurate judgment. Therefore, long-term cohort studies with the latest data are necessary to validate the possible causal association between common chronic diseases and depression.

Therefore, the current study aimed to analyze the latest causal relationship between depression and common chronic diseases in the population aged 45 years and older using a cohort data (2011–2018) from the China Health and Retirement Longitudinal Study (CHARLS) (31). Specifically, this study focused on the following issues: 1) whether having chronic diseases increases the risk of depression in middle-aged and older adults compared to those who do not have chronic diseases, 2) the relationship between the risk of depression and the number of chronic diseases suffered, and whether there are differences in the influencing factors of depression and its risk after stratification according to regions, 3) which specific chronic diseases increase the risk of depression, and 4) whether there are interaction effects of social activity participation, age, and chronic disease status on the incidence of depression.

2. Materials and methods

2.1. Population

The data for this study were obtained from the CHARLS, an extensive interdisciplinary survey funded by Peking University, which aims to collect a set of high-quality microdata broadly representative of individuals and households of the middle-aged and older adult population over 45 years old in China (32). The information includes basic personal information, health status, income and asset status, etc. It is used to analyze the aging situation of the Chinese population, promote interdisciplinary research on the aging issues, and provide a more scientific foundation for formulating and improving relevant policies in China. CHARLS used stratified sampling and Probability-Proportional-to-Size sampling (PPS) to conduct follow-up surveys in 150 counties and 450 communities (villages) in 28 provinces (autonomous regions and municipalities directly under the central government) in 2011, 2013, 2015, and 2018, respectively. As such, CHARLS data are widely representative and reflect the overall situation of the middle-aged and older adult groups in Chinese urban and rural areas.

This study used data from four survey studies, 2011, 2013, 2015, and 2018, with a baseline data (2011) of 17,705 individuals. According to the design of the present study, 2,817 individuals were excluded due to missing essential information (age, gender, education, marital status, etc.) in the baseline data, 1,659 were excluded because of the lack of a depression survey at baseline, 640 were excluded because of missing information in the chronic disease survey, and 245 were eliminated because they were below 45 years of age. In addition, this study used a cohort study design that required the removal of respondents who were already suffering from depression at baseline (2011), so 4,660 participants were excluded from our study, and 521 were excluded due to a lack of data on depression assessment during

follow-up. Therefore, 7,163 participants were finally included in this study for analysis. Figure 1 shows the screening process of the sample population.

2.2. Assessment of the depression

The depression of the respondents in our study was assessed using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10) (33, 34). Previous research has shown that the CES-D-10 demonstrated excellent internal consistency (Cronbach $\alpha = 0.69$–0.89), sensitivity (71.4–84.6%), and specificity (72.6–95%) for depression screening (35). In addition, the CES-D-10 has been fully validated in the Chinese older adult population to demonstrate its satisfactory reliability and validity (36, 37). The scale evaluates the respondent's psychological situation in the past week. It comprises questions in 10 aspects: "I was bothered by things that do not usually bother me," "I had trouble keeping my mind on what I was doing," "I felt depressed," "I felt everything I did was an effort," "I felt hopeful about the future," "I felt fearful," "My sleep was restless," "I was happy," "I felt lonely," and "I could not get going." The choices were "Rarely or none of the time (<1 day)," "Some or a little of the time (1–2 days)," "Occasionally or a moderate amount of the time (3–4 days)," and "most of the time (5–7 days)," which were scored 0~3, and two questions reflecting positive sentiment (I felt hopeful about the future, I was happy) were achieved in reverse (3~0). The final score was calculated by adding the scores of the ten questions. The total scores ranged from 0 to 30, and the participants were considered with depression when the total score was ≥10 (9, 38, 39).

2.3. Assessment of the chronic diseases

The chronic diseases were determined by a surveyor using the question "Have you been diagnosed with … by a doctor," and the participants were asked each of the following 13 categories of chronic diseases: hypertension, dyslipidemia (elevation of low-density lipoprotein, triglycerides (TGs), and total cholesterol, or a low high-density lipoprotein level), diabetes or high blood sugar, cancer or malignant tumor (excluding minor skin cancers), chronic lung diseases [such as chronic bronchitis, emphysema (excluding tumors or cancer)], liver disease (except fatty liver, tumors, and cancer), heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems, stroke, kidney disease (except for tumor or cancer), stomach or other digestive diseases (except for tumor or cancer), memory-related disease, arthritis or rheumatism, asthma. For each of these chronic diseases, respondents were given a score of "1" if they reported having an illness and "0" if they did not. Finally, the chronic disease scores were added up to the number of chronic diseases suffered by the respondents, and the number of chronic diseases ≥2 was considered "multimorbidity" (8).

2.4. Other covariates

The covariates included age, gender, the highest level of education, marital status, health insurance status, nighttime sleep duration, drinking status, smoking status, social activity participation, income status, body mass index (BMI), and region. Existing research demonstrates that these variables might be associated with depression (14, 40). In our study, data for chronic diseases and covariates were obtained from the baseline investigation (2011), and depression assessment data were collected from each follow-up survey (2011–2018). Appendix 1 shows the code for all variables and their problem descriptions.

In our study, we categorized participants' highest level of education into primary school and below, middle school, high school and above. Marital status was separated into married, divorced, widowed, and unmarried. The types of health insurance in the original survey data were classified as urban and rural resident medical insurance, long-term care insurance, urban employee medical insurance, private medical insurance and government medical insurance, etc. In this study, a respondent was considered covered by medical insurance if they participated in any of these. Participants were interviewed about their sleep status using the question "During the past month, how many hours of actual sleep did you get at night (average hours for one night)," and we grouped the hours of sleep reported by participants into <5 h, 5–8 h and >8 h. Drinking status was divided into greater than once a month, less than once a month and never. Smoking status was categorized as current smoker, former smoker and never smoked. The question "Have you done any of these activities in the last month" was used to ask participants about social activities, including interacting with friends, doing voluntary or charity work, using the internet, and other types of social activities, etc. Respondents who engaged in any of these social activities were considered socially active. BMI was divided into four groups: less than 18.5 kg/m^2 (underweight), 18.5~24 kg/m^2 (normal weight), 24~28 kg/m^2 (overweight), and more than 28 kg/m^2 (obese) (41, 42). The region was divided into Eastern, Central, and Western, and because of the small sample size of three provinces in the Northeast (Jilin, Heilongjiang, and Liaoning), we included them in the Central region for analysis.

2.5. Statistical analysis

The Mean ± standard deviation ($\bar{x} \pm SD$) was used for the statistical description of the continuous numerical variables, and
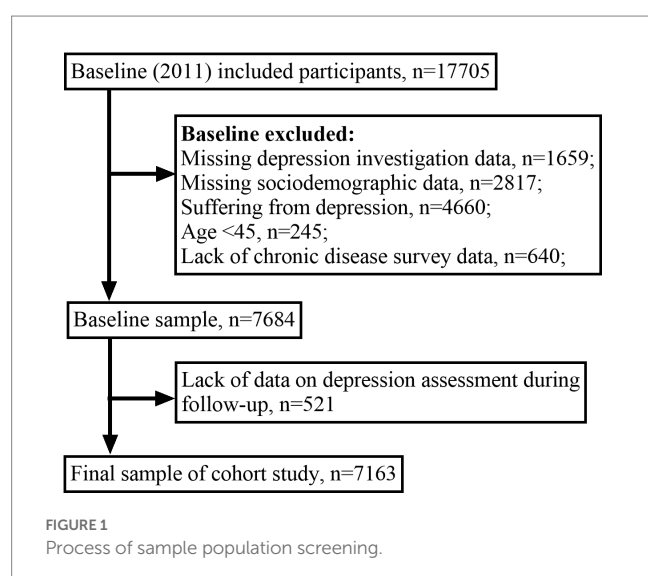
frequency (n) and percentage (%) were used for the statistical description of the categorical variables in our study. The Kaplan–Meier (K-M) method and Cox proportional hazards regression models were used to explore the association between each baseline characteristic, chronic diseases, and depression. The trend tests were used to analyze the change in the risk of depression with the increasing number of chronic diseases.

Firstly, the univariate Cox proportional hazards regression model was used to assess the association of each baseline covariate with depression and to estimate the hazard ratio (HR) and its 95% confidence interval (95% CI). The Kaplan–Meier method was then adopted to evaluate relationship between the chronic diseases and depression and to plot the incidence curves. After including each covariate, the association between the number of chronic diseases and depression was explored using a multivariate Cox proportional hazards regression model, adjust HR and 95% CI were calculated. Then, we stratified by region and constructed three multivariate regression models using Cox proportional hazards regression to examine whether there were significant differences in risk factors for depression and their risks between regions. Thirdly, we evaluated the relationship between each chronic disease and depression by enrolling 13 chronic diseases in a Cox proportional hazards regression model after adjusting for the effects of all covariates. Finally, we explored whether there were interaction effects of social activity participation, age, and chronic disease status on the incidence of depression by dividing the sample population into four categories, namely, "Middle-aged–Have social activity," "Middle-aged–No social activity," "Older adult–Have social activity," and "Older adult–No social activity". In the Cox proportional hazards regression, when the HR is greater than 1 and the 95% CI does not include 1, it indicates a higher risk of depression in this group than in the control group, while the opposite is true for HR less than 1. The SPSS 26.0 (SPSS Inc., Chicago, IL, United States) was used for all statistical analyzes in this study, and differences were considered statistically significant at $p < 0.05$.

3. Result

3.1. Sample characteristics

There was a total of 7,163 participants aged 45 years or older included in this study, of whom 3,793 (53.0%) were male and 3,370 (47.0%) were female. The age range was 45–93 years, with a mean age of 58.4 ± 9.0 years (median age 57 years), and the middle-aged population under 60 years was 58.6%. Most participants were characterized as having an elementary school education or less (62.3%), being married (90.8%), having health insurance (94.2%), and having no income (80.6%). At a mean follow-up of 5.08 ± 2.08 years, depression was reported in 2951 (41.2%; 95% CI: 40.1–42.3%) of 7,163 participants, with a cumulative incidence of 35.0% (95% CI: 33.5–36.5%) in male and 48.2% (95% CI: 46.5–49.9%) in female. The baseline chronic disease prevalence in the sample population was 60.7%, with 29.4% of patients with multiple diseases and 12.1% with three or more chronic diseases. The prevalence of chronic diseases among middle-aged people under 60 years old was 56.1, and 67.3% for those aged 60 years and above. The highest prevalence of chronic diseases at baseline were arthritis or rheumatism, hypertension, and

stomach or other digestive diseases, with prevalence rates of 26.9, 21.8, and 18.0%, respectively.

3.2. Relationship between covariates and depression

The association of each covariate with the hazard of developing depression was estimated using the univariate Cox proportional hazards regression model. The results suggested that all variables except age and health insurance were significantly related to depression ($p < 0.05$). The middle-aged and older adult Chinese characterized as female, lower education, widowed, not getting enough sleep, never smoking or drinking, lacking social activities, no income, low BMI, and less developed regions (Central and Western) were more likely to develop depression (Table 1).

3.3. Relationship between chronic diseases and depression

We evaluated the association between baseline chronic disease and depression by employing the Kaplan–Meier method and Cox proportional hazards regression models. Findings revealed that chronic disease at baseline was at a significantly higher risk of developing depression relative to those who did not have any chronic disease (Log-rank test: $\chi^2 = 47.759$, $p < 0.001$) (Figure 2). Furthermore, the risk of developing depression in the population increased significantly with the number of chronic diseases (Log-rank test: $\chi^2 = 57.993$, $p < 0.001$, p-trend < 0.001) (Figure 3). After adjusting for the impact of covariates in the multivariate Cox proportional hazards regression model, we found that as the number of chronic diseases increased, the risk of developing depression increased (p-trend < 0.001) (Figure 4).

After stratifying by region, the current study found some differences in the risk relationship between chronic diseases and depression among the Eastern, Central, and Western populations, as well as some differences in risk factors for depression among the regions. In terms of differences in risk factors, the risk of depression among middle-aged and older adult people in the Eastern region was influenced by health insurance status and BMI, while significant differences were observed between gender, social activity participation, and income status in the Central and Western regions (Table 2).

Furthermore, our study included 13 kinds of chronic diseases in the covariate-adjusted multivariate Cox proportional hazards regression model, to examine each of the chronic diseases on depression. The results of the analysis showed that diabetes or high blood sugar, kidney disease, stomach or other digestive diseases, and arthritis or rheumatism significantly raised the risk of depression in our study population (Figure 5).

3.4. Interaction effects of social activity participation, age, and chronic disease status on the incidence of depression

The results of the interaction effects analysis indicated that there were interaction effects of chronic disease status, age, and social

TABLE 1 Baseline characteristics and incidence of depression in 7163 participants, *n* (%).

Variables	Total	Depression situation		Crude *HR* (95% CI)	*p*
		No	Yes		
Total	7,163 (100)	4,212 (58.8)	2,951 (41.2)		
Age (year)					
<60	4,201 (58.6)	2,451 (58.3)	1750 (41.7)	1	
≥60	2,962 (41.4)	1761 (59.5)	1,201 (40.5)	1.027 (0.954,1.105)	0.483
Gender					
Male	3,793 (53.0)	2,466 (65.0)	1,327 (35.0)	1	
Female	3,370 (47.0)	1746 (51.8)	1,624 (48.2)	1.451 (1.349,1.560)	<0.001
Highest level of education					
High school and above	1,002 (14.0)	724 (72.3)	278 (27.7)	1	
Middle school	1,698 (23.7)	1,080 (63.6)	618 (36.4)	1.340 (1.164,1.544)	<0.001
Primary school and below	4,463 (62.3)	2,408 (54.0)	2055 (46.0)	1.802 (1.590,2.043)	<0.001
Marital status					
Married	6,506 (90.8)	3,845 (59.1)	2,661 (40.9)	1	
Divorced	69 (1.0)	44 (63.8)	25 (36.2)	0.870 (0.586,1.289)	0.487
Widowed	551 (7.7)	305 (55.4)	246 (44.6)	1.222 (1.072,1.392)	0.003
Unmarried	37 (0.5)	18 (48.6)	19 (51.4)	1.321 (0.841,2.074)	0.227
Health insurance status					
Yes	6,744 (94.2)	3,982 (59.0)	2,762 (41.0)	1	
No	419 (5.8)	230 (54.9)	189 (45.1)	1.157 (0.999,1.341)	0.052
Nighttime sleep duration (hour)					
>8	2,467 (34.4)	1,513 (61.3)	954 (38.7)	1	
5–8	4,033 (56.3)	2,394 (59.4)	1,639 (40.6)	1.006 (0.984,1.154)	0.119
<5	663 (9.3)	305 (46.0)	358 (54.0)	1.569 (1.389,1.772)	<0.001
Drinking status					
>Once/month	2012 (28.1)	1,307 (65.0)	705 (35.0)	1	
<Once/month	602 (8.4)	375 (62.3)	227 (37.7)	1.074 (0.925,1.247)	0.349
Never	4,549 (63.5)	2,530 (55.6)	2019 (44.4)	1.326 (1.217,1.445)	<0.001
Smoking status					
Current smoker	2,388 (33.3)	1,500 (62.8)	888 (37.2)	1	
Former smoker	670 (9.4)	436 (65.1)	234 (34.9)	0.950 (0.823,1.098)	0.490
Never smoked	4,105 (57.3)	2,276 (55.4)	1829 (44.6)	1.233 (1.138,1.335)	<0.001
Social activity participation					
Yes	3,889 (54.3)	2,418 (62.2)	1,471 (37.8)	1	
No	3,274 (45.7)	1794 (54.8)	1,480 (45.2)	1.236 (1.150,1.328)	<0.001
Income status					
Yes	1,393 (19.4)	959 (68.8)	434 (31.2)	1	
No	5,770 (80.6)	3,253 (56.4)	2,517 (43.6)	1.497 (1.352,1.658)	<0.001
BMI (kg/m²)					
18.5~24	3,712 (51.8)	2,195 (59.1)	1,517 (40.9)	1	
<18.5	359 (5.0)	191 (53.2)	168 (46.8)	1.265 (1.079,1.484)	0.044
24~28	2,208 (30.8)	1,301 (58.9)	907 (41.1)	0.984 (0.906,1.069)	0.703
>28	884 (12.3)	525 (59.4)	359 (40.6)	0.981 (0.874,1.100)	0.738

(Continued)

TABLE 1 (Continued)

Variables	Total	Depression situation		Crude *HR* (95% CI)	*p*
		No	Yes		
Region					
Eastern	2,472 (34.5)	1,631 (66.0)	841 (34.0)	1	
Central	2,629 (36.7)	1,527 (58.1)	1,102 (41.9)	1.252 (1.144,1.369)	<0.001
Western	2062 (28.8)	1,054 (51.1)	1,008 (48.9)	1.536 (1.402,1.684)	<0.001

FIGURE 2
Effect of participant's baseline chronic disease status on the incidence of depression. The incidence of depression was significantly higher in participants with chronic disease than in those without chronic disease at baseline ($HR = 1.330$, 95% *CI*: 1.227–1.442, $p < 0.001$).

FIGURE 3
Effect of the number of participants' baseline chronic diseases on the incidence of depression. The incidence of depression increased significantly with the increasing number of chronic diseases at baseline (*p*-trend <0.001). Relative to participants without chronic diseases, the risk of depression for participants with one chronic disease: $HR = 1.203$, 95% *CI*: 1.101–1.313; for participants with two chronic diseases: $HR = 1.316$, 95% *CI*: 1.187–1.459; and for participants with three or more chronic diseases: $HR = 1.406$, 95% *CI*: 1.253–1.577. All $p < 0.001$.

FIGURE 4
Adjust hazard (*HR*) and its 95% confidence interval (95% *CI*) of the number of the chronic diseases at baseline. The Cox proportional hazards regression model was adjusted for age, gender, highest level of education, marital status, health insurance, nighttime sleep duration, drinking status, smoking status, social activity participation, income status, and BMI, *$p < 0.001$. The risk of developing depression increased significantly with the number of chronic diseases at baseline (*p*-trend < 0.001). Relative to participants without chronic diseases, the risk of depression for participants with one chronic disease: $HR_{adjust} = 1.197$, 95% *CI*: 1.096–1.308; for participants with two chronic diseases: $HR_{adjust} = 1.310$, 95% *CI*: 1.180–1.454; and for participants with three or more chronic diseases: $HR_{adjust} = 1.397$, 95% *CI*: 1.241–1.572. All $p < 0.001$.

4. Discussion

At present, the CHARLS is one of the most representative sociodemographic investigations in China, with its long-term period, broad survey scope, and various research variables. In the current study, we analyzed the relationship between the chronic disease and depression among middle-aged and older adult people aged 45 years and older in China using the cohort data from CHARLS 2011–2018. We observed that participants with chronic diseases were at higher risk of depression, and the risk was directly proportional to the number of chronic diseases. Further analysis of chronic conditions revealed that suffering from diabetes or high blood sugar, kidney disease, stomach or other digestive diseases, and arthritis/rheumatism increased the risk of depression significantly. In addition, there are some differences in the influencing factors of depression and its risk between different regions. In summary, our study illustrates the crucial role of chronic diseases in the occurrence of depression, and it guides the prevention and treatment of depression in middle-aged and older adult adults in China.

activity participation on the incidence of depression. Specifically, the incidence of depression was lower among individuals who engaged in social activities, both in the middle-aged group (<60 years) and older adult group (≥60 years); and the incidence of depression was significantly higher in the middle-aged group compared to the older adult group, regardless of their participation in social activities (Figure 6).

TABLE 2 Association between each variable and depression after stratification by region.

Variables	Model 1 (Eastern)		Model 2 (Central)		Model 3 (Western)	
	HR (95% CI)	p	HR (95% CI)	p	HR (95% CI)	p
Age (year)						
<60	1		1		1	
≥60	0.864 (0.741, 1.007)	0.062	0.865 (0.757, 0.989)	0.033	0.927 (0.808, 1.064)	0.284
Gender						
Male	1		1		1	
Female	1.134 (0.923, 1.392)	0.231	1.421 (1.191, 1.696)	<0.001	1.447 (1.200, 1.744)	<0.001
Highest level of education						
High school and above	1		1		1	
Middle school	1.586 (1.204, 2.089)	0.001	1.137 (0.917, 1.410)	0.241	1.195 (0.911, 1.567)	0.198
Primary school and below	1.821 (1.413, 2.347)	<0.001	1.410 (1.155, 1.721)	<0.001	1.576 (1.229, 2.021)	<0.001
Marital status						
Married	1		1		1	
Divorced	1.019 (0.525, 1.980)	0.956	0.888 (0.359, 1.997)	0.775	1.070 (0.571, 2.006)	0.833
Widowed	1.234 (0.960, 1.610)	0.099	1.064 (0.847, 1.336)	0.596	0.966 (0.768, 1.215)	0.765
Unmarried	1.411 (0.695, 2.864)	0.341	1.107 (0.411, 2.980)	0.841	1.652 (0.775, 3.522)	0.194
Health insurance status						
Yes	1		1		1	
No	1.363 (1.032, 1.802)	0.029	0.935 (0.728, 1.201)	0.935	1.145 (0.893, 1.468)	0.285
Nighttime sleep duration (hour)						
>8	1		1		1	
5–8	1.090 (0.939, 1.265)	0.259	1.084 (0.950, 1.236)	0.229	1.125 (0.980, 1.293)	0.095
<5	1.599 (1.242, 2.058)	<0.001	1.377 (1.129, 1.680)	0.002	1.305 (1.067, 1.596)	0.010
Drinking status						
>Once/month	1		1		1	
<Once/month	1.042 (0.782, 1.390)	0.777	1.071 (0.836, 1.372)	0.588	1.023 (0.791, 1.324)	0.860
Never	1.186 (0.981, 1.435)	0.078	1.120 (0.948, 1.323)	0.181	0.950 (0.804, 1.122)	0.545
Smoking status						
Current smoker	1		1		1	
Former smoker	0.916 (0.707, 1.187)	0.508	0.883 (0.694, 1.125)	0.315	1.107 (0.854, 1.434)	0.443
Never smoked	1.001 (0.816, 1.230)	0.959	0.916 (0.768, 1.092)	0.327	0.962 (0.798, 1.161)	0.688
Social activity participation						
Yes	1		1		1	
No	1.084 (0.945, 1.245)	0.249	1.136 (1.007, 1.281)	0.038	1.218 (1.072, 1.383)	0.003
Income status						
Yes	1		1		1	
No	1.117 (0.941, 1.327)	0.207	1.203 (1.000, 1.447)	0.050	1.265 (1.002, 1.597)	0.048
BMI (kg/m^2)						
18.5~24	1		1		1	
<18.5	1.235 (0.898, 1.697)	0.194	1.172 (0.888, 1.545)	0.262	1.142 (0.887, 1.472)	0.304
24~28	1.015 (0.900, 1.226)	0.530	0.977 (0.852, 1.121)	0.740	0.962 (0.826, 1.121)	0.623
>28	0.770 (0.615, 0.964)	0.023	0.973 (0.805, 1.175)	0.775	1.006 (0.814, 1.242)	0.958
Number of chronic diseases						
0	1		1		1	
1	1.156 (0.982, 1.359)	0.081	1.208 (1.042, 1.400)	0.012	1.230 (1.056, 1.433)	0.008

(Continued)

Variables	Model 1 (Eastern)		Model 2 (Central)		Model 3 (Western)	
	HR (95% CI)	p	HR (95% CI)	p	HR (95% CI)	p
2	1.356 (1.108, 1.660)	0.003	1.416 (1.193, 1.681)	<0.001	1.204 (1.010, 1.435)	0.038
3+	1.367 (1.081, 1.728)	0.009	1.434 (1.188, 1.730)	<0.001	1.385 (1.129, 1.699)	0.002
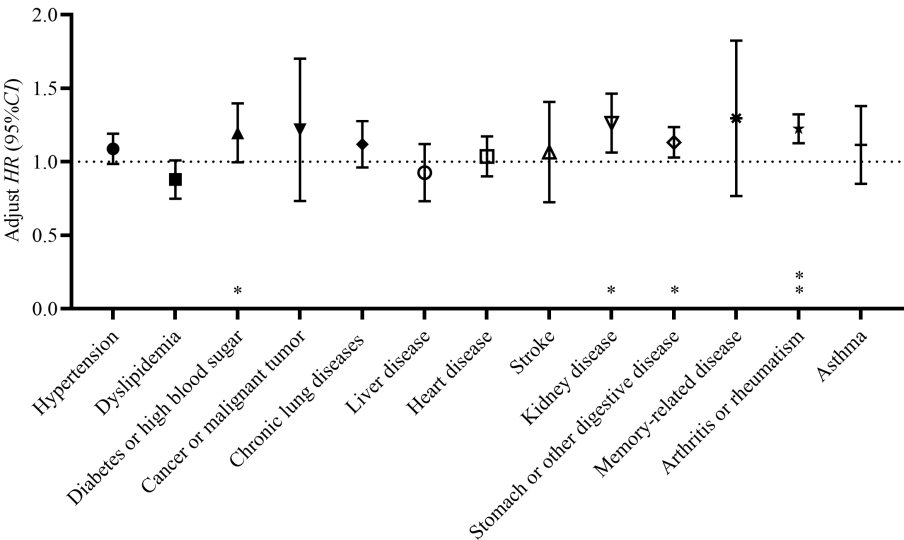
FIGURE 5
Adjust hazard (HR) and its 95% confidence interval (95% CI) of having different kinds of chronic diseases at baseline. The Cox proportional hazards regression model was adjusted for age, gender, highest level of education, marital status, health insurance, nighttime sleep duration, drinking status, smoking status, social activity participation, income status, BMI and other types of chronic diseases, *$p < 0.05$; **$p < 0.001$. Having the diabetes or high blood sugar, kidney disease, stomach or other digestive diseases, and arthritis or rheumatism at baseline significantly increased the risk of developing depression in participants. Diabetes or high blood sugar: $HR_{adjust} = 1.185$, 95% CI: 1.001–1.403; Kidney disease: $HR_{adjust} = 1.252$, 95% CI: 1.067–1.468; Stomach or other digestive disease: $HR_{adjust} = 1.128$, 95% CI: 1.029–1.236; Arthritis or rheumatism: $HR_{adjust} = 1.221$, 95% CI: 1.127–1.323.
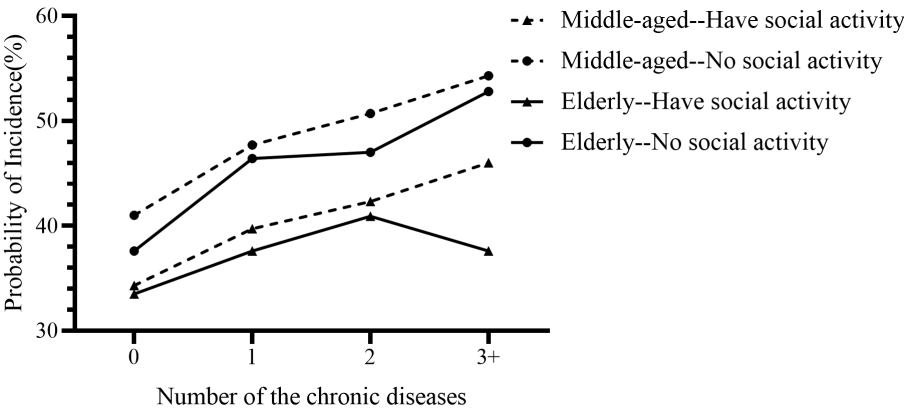
FIGURE 6
Interaction effects of social activity participation, age, and chronic disease status on the prevalence of depression. The prevalence of depression was higher in both middle-aged and older adult participants who had no social activity than in those who had social activity, and both in the had social activity and had no social activity groups, the prevalence of depression was lower in the older adult than in middle-aged adults.

4.1. The prevalence of depression in Chinese middle-aged and older adult populations is dismal

After seven years of follow-up, 41.2% of the sample population reported depression, which is higher than several previous studies on depression (9, 14, 43), suggesting that the status of depression in the Chinese population is not optimistic. However, the studies showed that the outpatient rate of depression is extremely poor, with only 5% of middle-aged and older adult people with depression being aware of their condition and 2% consistently seeking treatment (43). The middle-aged and older adult Chinese populations are strongly

influenced by traditional concepts and generally have a low level of education, so they did not form a correct awareness of depression, and consider it a "shame" to suffer from depression. Researches have shown that older and lower-educated people hold higher levels of stigma about depression (44, 45). The stigma attached to depression can seriously hinder the recovery of the social functioning of patients, making them more vulnerable to misunderstanding and discrimination (46), thus reducing their willingness to seek medical care and increasing their risk of suicide (47, 48).

4.2. There was a dose–response relationship between the number of chronic diseases and the risk of depression

According to our study, suffering from different levels of chronic disease increased the risk of developing depression among participants. A similar study reported that chronic diseases were related to a significantly higher risk of depression ($HR = 1.38$), and this risk increased with the number of chronic diseases (9). Additionally, a meta-analysis found that the people with multiple diseases had twice the risk of depression as those without multiple diseases ($RR = 2.13$, $p < 0.001$), and the odds of depression were 45% higher for each additional chronic disease compared with those without chronic disease ($OR = 1.45$, $p < 0.001$) (25). We supposed that chronic diseases are difficult to cure for a long time, and will cause a substantial psychological and physiological burden to patients, and some of them even resist the long-term tedious disease treatment. When suffering from multiple chronic diseases, the negative emotions may get worse with the number of chronic diseases they suffer from, and the accumulation of negative emotions over time will most likely lead to depression. Besides, one of the contributors to the increased vulnerability to depression in patients with chronic diseases is economic factors. Most chronic diseases are long-lasting, and some are even incurable, requiring lifelong treatment, which will impose a tremendous financial burden and additional labor losses on patients and their families (49, 50). It has been found that 63.96% of the total expected medical expenses for the older adult in rural areas of China are for chronic diseases (50), and the enormous medical expenses will increase the psychological stress of the patients and lead to depression.

4.3. Certain specific diseases (diabetes, kidney disease, stomach or other digestive disease, and arthritis or rheumatism) increase the risk of depression significantly

Furthermore, our study found that patients suffering from diabetes or high blood sugar, kidney disease, stomach or other digestive diseases, and arthritis or rheumatism has a significantly increased risk of depression, and the highest risk was found for kidney disease. Zheng also discovered that chronic kidney disease raised the risk of depression in the middle-aged and older adult population ($OR = 1.48$, $p < 0.05$) (21). We supposed that chronic kidney disease has a recurrent course and low curative rate, and treatment such as hemodialysis and peritoneal dialysis is required. Patients must endure the devastating effects of the complex disease treatment process and

side effects on their family, work employment, mental health, and freedom for a long time (51–53), and long-term poor emotions will develop depression. It is also important to note that patients with arthritis or rheumatism face a high risk of depression because arthritis or rheumatism causes persistent pain, resulting in loss of appetite, mobility, poor sleep, and even loss of function, which can significantly affect patients' daily life and lead to the anxiety and depression (54), about 30% of patients with rheumatoid arthritis developed depression within 5 years of disease diagnosis (55). Additionally, studies have shown particular biological interactions between the immune system and the central nervous system (56). Some inflammatory factors [such as interleukin-1 (IL-1), tumor necrosis factor- (TNF) and IL6] enter the central nervous system through humoral or neuronal pathways and disrupt its normal functioning, resulting in the development of mental disorders (57, 58), and these inflammatory factors have also been demonstrated to be associated with the duration and severity of depression (57). Furthermore, through being implicated in the etiology of pain and weariness, these inflammatory factors indirectly contribute to depression (57).

4.4. The risk of depression is significantly higher among female than male in the middle-aged and older adult population

Through univariate Cox proportional hazards regression model analysis, the current study found that the risk of depression was significantly higher among females than males, which was consistent with the findings of several previous studies (9, 59–62). The main reasons included the higher average life expectancy of women compared to men, thus resulting in a higher rate of widowhood, and the difficulty for female seniors to adapt to life and emotional changes in the short term, which leads to feelings of loneliness (29). Furthermore, the women faced fewer education opportunities, poor economic situation, and poor social competitiveness compared to the men, which may also contribute to a greater risk of depression in older adult women. Moreover, due to the rapid changes in their physical condition and hormone levels, middle-aged women are prone to the "menopause syndrome" during and after perimenopause, resulting in symptoms such as menstrual disorders, dizziness, body pain and hot flashes. Also, the menopausal women are more likely to develop sleep disorders and sexual dysfunction, which can seriously reduce the quality of life and increase the risk of depression (63, 64). For this reason, we should be more concerned about the mental health of women and provide them with more support in disease prevention and social security.

4.5. Several sociodemographic and lifestyle factors have significant effects on the risk of depression

Moreover, several sociodemographic and lifestyle factors, such as sleep duration, participation in social activities, and socioeconomic standing, have a substantial influence on depression. Our research revealed that those who get insufficient sleep had a higher risk of depression (<5 h/d: Crude $HR = 1.569$). That is because

adequate sleep is a necessary prerequisite for maintaining physiological health, and when lacking sufficient hours of sleep, it is difficult to maintain the homeostasis of the organism and prone to various diseases (65, 66). Compared to youthful people, middle-aged and older adult adults generally have a shorter sleep duration and poorer sleep quality (67–69), thus being more vulnerable to melancholy. Previous research has demonstrated that reduced sleep duration over short periods of time is associated with impaired emotional functioning, memory, and attention (70), and that changes in sleep duration may lead to alterations or disruptions of circadian rhythms, as well as circadian rhythms may regulate mood, according to some evidence (71, 72). Additionally, poor social activity is a significant risk factor for depression, and numerous studies have demonstrated a strong negative correlation between depression and social activity (73–75), the results of the interaction effects analysis in the current study also showed that whether in the middle-aged or older adult population, the incidence of depression was higher in the had no social activity group than the had social activity group. On the one hand, abundant social activities may increase the psychological satisfaction of life, as well as their sense of well-being and social support (76, 77), thereby alleviating the depressive state. On the other hand, social activities enable the older adult to engage in more physical activity, which can significantly enhance their physical condition and cognitive ability (77, 78) and decrease the risk of depression (79, 80). In addition, economic status exerts a greater influence on depression, with the current study revealing a substantially higher risk of depression in those without income than in those with income (Crude HR = 1.497). Inferior socioeconomic status impairs the capacity to process negative emotions, resulting in increased cognitive and negative emotional vulnerability (16, 81), and individuals with poorer economic status often struggle to access long-term, professional mental health services, leaving them without depression diagnosis and treatment (81). Apart from personal economic status, community economic status is equally crucial for health (82–85), and the double jeopardy hypothesis suggests that people living in communities with lower socioeconomic status are less healthy than those living in regions with higher socioeconomic status because they are more likely to be exposed to a greater lack of public health services and community health resources (86–88). Therefore, in terms of health policy, we recommend that government departments prioritize the mental health of those residing in lower socioeconomic status regions, who are entitled to receive community-based health care services regardless of their individual socioeconomic status.

4.6. China should take effective measures to protect the mental health of middle-aged and older adult people, especially those suffering from chronic diseases

In summary, the middle-aged and older adult with chronic diseases were more likely to develop depression, and these findings provide targets for future aging research and public health interventions in China, where current policies need to increase investment and attention to mental health support for patients with chronic diseases. It is essential to provide extensive health education to those who are generally less educated, to make them correctly understand depression, and to strengthen mental health education and knowledge dissemination among social workers, volunteers and family members to cultivate a positive mindset and an optimistic worldview among the middle-aged and older adult. The public also needs to be guided to reduce disease discrimination, help patients with depression build confidence, and increase the rate of depression diagnosis. In addition, the government should take a series of measures to safeguard the mental health of patients with chronic diseases, such as increasing social benefits (e.g., pensions), improving their living standards, and scheduling frequent follow-up visits with patients. In terms of preventing chronic diseases, efforts should be increased to prevent and treat chronic diseases, encourage regular medical checkups for middle and older adults, and detect and treat various chronic diseases at an early stage. Furthermore, it is necessary to strengthen the collaboration between medical institutions and family solidarity to improve the quality of treatment for middle-aged and older adult patients and reduce the possibility of transformation of chronic diseases into depression; as well as to expand the medical insurance coverage of chronic disease drugs to reduce the economic burden of chronic disease patients, thus indirectly improving the mental health status of the sick population. Another objective is required to focus on screening for depression in people with chronic diseases, such as free depression screening in primary hospitals, as well as an early and inexpensive intervention treatment for people with the disease to prevent its deterioration and reduce the suicide rate in people with depression. All in all, China should pay more attention to the mental health problems of middle-aged and older adult people, improve primary medical conditions and social support services, and provide a full range of treatment, management and rehabilitation services for patients through the construction of health information technology in multiple sites. At the same time, targeted preventive and therapeutic measures are taken for different types of chronic diseases to reduce the negative effects of chronic diseases and decrease the incidence of depression. In addition, our study found that there were some differences in risk factors for depression in different regions, and relevant authorities should consider these factors when formulating depression prevention and treatment policies and adopting appropriate countermeasures for populations in different regions.

There are also some limitations to our study. First, we did not consider possible changes in variables with follow-up time when examining the relationship between each baseline characteristic and depression. Secondly, the chronic diseases and depression status investigations were based on participants' self-reports, which may generate various degrees of recall bias and thus deviance in assessing the relationship between chronic diseases and depression. In addition, the covariates included in the present study were based on extensive literature reading and expert consultation, certain variables with implications for depression may not have been considered in this study. Finally, the sample population of the current study excluded those who resided in orphanages and older adult institutions, whose mental health status may have been worse than that of the older adult who lived at home, during the original data sampling phase.

5. Conclusion

The current study revealed a dose–response relationship between chronic diseases and the risk of depression in the middle-aged and

older adult Chinese population, as well as the significant impact of certain diseases on the risk of depression. It could serve as a guide for the prevention and treatment of depression in this population, and relevant authorities should prioritize the mental health of people with chronic diseases when formulating disease prevention and treatment policies to reduce the incidence and disease burden of depression and improve the quality of life of the middle-aged and older adult population. Compared to other studies of the same type, our study features a large sample size, a lengthy follow-up period, and the use of the most recent CHARLS data, allowing for a more accurate assessment of the association between chronic disorders and depression. However, the focus of the current study was on the number of chronic diseases and the effect of specific chronic diseases on depression, without exploring the effect of the combination of different types of chronic diseases and their interaction on depression, a topic that will require further investigation in the future.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: http://charls.pku.edu.cn. The database is free and open to scholars worldwide.

Ethics statement

The studies involving human participants were reviewed and approved by CHARLS was ethically approved by the Ethics Review Board of the Peking University (approval number: IRB00001052-11015), and each respondent signed an informed consent form. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

PZ, YL, and XY designed the research program. JP and WG performed the statistical analysis. QL processed the figures and table.

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.2023.1176669/full#supplementary-material

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Satisfaction with medication in older adult patients with chronic respiratory diseases: a multicenter cross-sectional observational study

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Purpose: To gain insight into medication satisfaction and factors associated with chronic respiratory disease, particularly chronic obstructive pulmonary disease (COPD) in older adults, focusing on public health issues and improving the health of the older adult population.

Methods: This cross-sectional study was conducted from October 2022 to November 2022 in 24 hospitals in different regions of Hunan Province, China. Older adult patient treatment satisfaction was assessed using the Treatment Satisfaction Questionnaire for Medication version II. Multiple regression analysis was used to identify factors independently associated with patient treatment satisfaction.

Results: Only 15.9% of all patients scored above 80 in the effectiveness domain, while 11.6 and 16.5% scored above 80 in the convenience and global satisfaction domains, respectively, while 17.3% reported having side effects. Interstitial lung disease was associated with lower drug satisfaction than other disorders ($p < 0.05$). Multifactorial regression analysis showed that age, education background, profession, and smoking status were independently associated with satisfaction among patients with chronic respiratory diseases ($p < 0.05$). Education background, profession, CAT score, number of acute exacerbations, duration of home oxygenation and duration of home ventilator use were independently associated with satisfaction in patients with COPD ($p < 0.05$).

Conclusion: Low satisfaction with chronic respiratory drug therapy was associated with age, education background, profession and smoking status. Satisfaction was lower for patients with interstitial lung disease. For COPD, CAT score, education background, profession, number of acute exacerbations, home oxygen and ventilator use influence satisfaction. Clinicians can identify appropriate patients and communicate effectively with them throughout treatment and follow-up, vigorously promote smoking cessation and home oxygen therapy, increase medication satisfaction, especially among older adults, and in turn improve public health and the quality of life of older adults.

1. Introduction

Chronic respiratory diseases are diseases of the respiratory tract and other structures of the lung and are among the leading causes of morbidity and mortality worldwide (1, 2). The most common chronic respiratory diseases are asthma, chronic obstructive pulmonary disease (COPD), and occupational lung diseases such as pneumoconiosis, thus contributing to the global burden of noncommunicable diseases with negative social and economic consequences (3). Although there is no cure for chronic respiratory disease, various forms of treatment can help control symptoms, improve patients' quality of life, and prevent the adverse outcomes (including exacerbation) associated with increased morbidity, increased health care use, disability, and risk of death (4). Statistics also reveal that the financial impact of treating chronic respiratory disorders on the economy of all nations is rising. Care for individuals with chronic respiratory disorders alone costs roughly €380 billion annually in the 28 EU member states as of 2019 (5). Importantly, chronic respiratory diseases disproportionately affect older adults, who often experience age-related physiological changes and are more susceptible to respiratory impairments (6). The aging population poses unique challenges in the realm of public health, as it necessitates a comprehensive understanding of the specific needs and considerations of older adult individuals (7). Aging is characterized by a complex interplay of biological, psychological, and social factors that can influence medication satisfaction and treatment outcomes (8). Therefore, public health efforts aimed at addressing chronic respiratory diseases must consider the implications of aging both from a population health standpoint and when working directly with older adult patients.

Commonly used drugs for chronic respiratory diseases are cough suppressants, expectorants, asthma suppressants and glucocorticoids. Cough suppressants mainly include central and peripheral cough suppressants. Expectorants are mainly divided into nausea expectorants, stimulant expectorants and mucolytics. Asthma medications are divided into bronchodilators, anti-allergic asthma medications and anti-inflammatory asthma medications. Glucocorticoids include inhaled glucocorticoids and oral glucocorticoids. If the respiratory tract infection is combined with bacterial infection, various antibiotics are also required for treatment (9–13). For example, COPD and asthma, are among the most common chronic respiratory diseases for which licensed therapies are effective in reducing symptom burden, improving health-related quality of life, and maintaining or slowing disease progression. However, reports of a large number of asthma and COPD exacerbations and associated stressors to emergency and respiratory care persist (14). The reason for this is mainly that efficacy outcomes from randomized controlled trials are usually characterized as well-controlled, highly selective, and short-term, whereas in real-life efficacy assessments often involve different patient populations, different care settings and patient characteristics, and longer time intervals (15). A study involving 401 people assessed the satisfaction of Italian COPD patients with their medication use. The study found that COPD patients were only moderately satisfied with their treatment. High patient satisfaction was mainly associated with low awareness of the disease, high adherence to treatment and lower levels of pain (16). Real-world data is essential to assess the effectiveness of licensed therapies, given the differences in the patient population and settings in which they are used. Indeed concerns regarding drug efficacy, adverse effects, dosing regimen and length of treatment are worthwhile. Both subjective and objective feelings can have a significant impact on a patient's adherence to the medication, which is crucial for the effective management of the disease. For example, if a patient experiences unpleasant side effects or discomfort while taking the medication, they may be less likely to adhere to the prescribed dosage or even stop taking the medication altogether. In contrast, if a patient perceives that the medication is working well and improving their symptoms, they may be more likely to stick to the treatment plan and achieve better outcomes.

The Treatment Satisfaction Questionnaire for Medication II (TSQM-II) is a validated instrument for investigating patient satisfaction with medication (17). The TSQM-II has been validated in a heterogeneous population and the questionnaire has been shown to have high internal consistency (18). In addition, the questionnaire has been used to assess medication satisfaction in a variety of conditions (19–21), and have proved that the Chinese version of the TSQM-II also has been validated in the Chinese population (22). Supplementary Table 2 provides an overview of the application of TSQM II in China and other countries. Therefore, exploring medication satisfaction among older adult individuals with chronic respiratory diseases within the broader public health context is essential for optimizing their care and well-being. The aim of this study was to investigate medication satisfaction in older adult patients with chronic respiratory diseases, especially the most common COPD patients, and to explore potential associated factors in China. The findings may offer insights and evidence to enhance patient medication satisfaction and inform shared decision-making in clinical practice.

2. Materials and methods

2.1. Patients

3,527 patients were recruited between October 2022 and November 2022 in 24 hospitals in different cities, counties and districts in Hunan Province, China, and information was collected using a self-administered questionnaire. Inclusion criteria were a history of ≥1 of the following previous medical conditions: respiratory diseases such as COPD, asthma, pulmonary hypertension, interstitial lung disease, obstructive sleep apnea/hypopnea syndrome (OSAHS), bronchiectasis, pneumoconiosis and other. Figure 1 is the flow chart of this study.

2.2. Methods

The general information questionnaire was developed by the investigators themselves after reviewing the literature and integrating expert opinions, and collected baseline information on age, gender, education background, profession, location developed/underdeveloped, smoking status, and residence (urban/rural). Among them, CAT score, mMRC score, home oxygen therapy, home non-invasive ventilation, and baseline information on history of acute exacerbation of COPD in the previous year were also collected for patients who filled in that they had COPD, which was defined as worsening symptoms requiring antibiotic medication, systemic corticosteroids (moderate), hospitalization, or a combination of the above (severe). The main observation was the second version of the satisfaction with medication (TSQM), which contains 11 questions

and can be divided into four sections: effectiveness score, side effect score, convenience score, and global satisfaction score, with a score range between 0 and 100, with higher scores associated with higher satisfaction levels. TSQM-II was previously used in China and the scores were calculated in the same way as in the original paper by Atkinson et al. (18, 23). Effectiveness: ([(Item 1 + Item 2) − 2] divided by 12) × 100. Side effects: ([(Sum of Item 4 to Item 6) − 3] divided by 12) × 100. Convenience: ([(Sum of Item 7 to Item 9) − 3] divided by 18) × 100. Global satisfaction: ([(Sum of Item 10 to Item 11) − 2] divided by 12) × 100. The study used voluntary responses to collect the questionnaires, and the questionnaires with complete information and no logical errors in the answers to the questions were judged as valid responses, otherwise they were not qualified. After collecting all the answer sheets, the proportion of each option for each question was counted, and the answer data were compared and analyzed.

2.3. Statistical analysis

SPSS 26.0 (IBM, NY, United States) was used for statistical analysis. The continuous variables were tested for normal distribution using the Kolmogorov–Smirnov test. The mean ± standard deviation (SD; normal distribution) and median (range; skewed distribution) were calculated for continuous variables. The Mann–Whitney U-test (skewed distribution) and the Student's t-test (normal distribution) were used for analysis. Categorical variables are presented as frequency (percentage) and were analyzed using the Chi-square test. The univariable linear regression analyses were performed for baseline characteristics of the patients to identify factors associated with the global satisfaction of patients ($p < 0.05$). Then, the significant variables were entered into a multivariable linear regression. The linear regressions were performed using the standardized TSQM-II total scores. p-values < 0.05 were considered statistically significant.

3. Results

3.1. Characteristics of the study population

A total of 3,527 questionnaires were sent out in this study, 92 were not completed after answering or failed the questionnaire, and 3,435 valid questionnaires were recovered, the recovery rate was 97.4%.
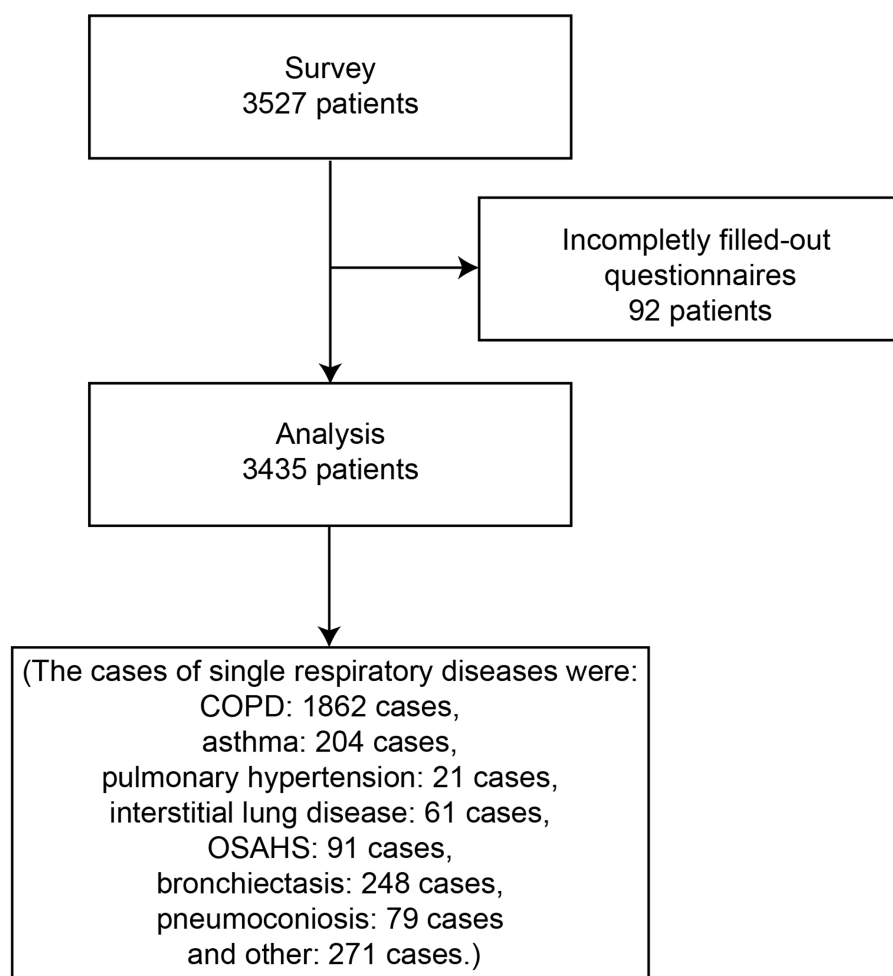
FIGURE 1
Patient flowchart.

Baseline information of patients with chronic respiratory diseases and their medication satisfaction scores are shown in Table 1. The patients were 67.10 ± 13.13 years old and 69.1% were male. The proportion of patients who are smoking is 18.1%, and the proportion of patients who have smoked before and never smoked is 41.4% and 40.6%, respectively. Further statistics yielded single respiratory diseases as COPD: 1,862 cases, asthma: 204 cases, pulmonary hypertension (including chronic pulmonary heart disease): 21 cases, interstitial lung disease: 61 cases, OSAHS: 91 cases, bronchiectasis: 248 cases, pneumoconiosis: 79 cases and other: 271 cases, respectively (Figure 2D). Baseline information about our patients with COPD of special interest is shown in Supplementary Table 1. In total, there were 2,218 COPD patients, 71.8% of whom were males, thus 356 patients with other combined respiratory diseases.

3.2. Scores of satisfaction

In Figure 2, patient satisfaction with medications for chronic respiratory disease, as measured by the TSQM II, was low, with only 15.9% of patients scoring above 80 in the effectiveness domain, compared with 11.6% and 16.5% in the convenience and overall satisfaction domains, respectively. The median total satisfaction score (25th–75th percentile) of 66.7 (58.3–66.7) in the effectiveness domain, with 74.8% of patients satisfied with the ability of the medication to prevent or treat, and 75.1% satisfied with the relief of symptoms caused by the medication; in the convenience domain median satisfaction was 66.7 (61.1–72.2), 77.8% of patients were satisfied with the ease of using the medication, 76.30% were satisfied with the ease of planning when to use the medication, and 70.10% were satisfied with the frequency of the medication; in the global satisfaction domain median satisfaction was 66.7 (58.3–66.7), 70.0% of patients were satisfied with the extent to which the benefits of the medication outweighed the disadvantages, and 75.7% of patients were satisfied with the medication when all things were taken into account. In addition patients reported side effects at a rate of 17.3% with a median overall score (25th–75th percentile) of 66.7 (50.0–66.7), with 45.4% of patients dissatisfied with side effects that interfered with physical health and ability to work (e.g., strength, energy), 48.2% dissatisfied with side effects that interfered with the ability to think (e.g., ability to think clearly, stay awake), and 43.9% of the patients were dissatisfied with the side effects that affected their emotions or mood (e.g., anxiety, fear, sadness, irritation).

In Figure 3, the distribution and characteristics of TSQM-II scores for single chronic respiratory diseases, including COPD, asthma, pulmonary hypertension, interstitial lung disease, OSAHS, bronchiectasis, pneumoconiosis, and other, are shown. It can be concluded that interstitial lung disease has lower effectiveness, convenience and global satisfaction scores than other diseases. In addition Figures 3D,E demonstrate the side effect reporting rates and side effect scores for different diseases, with interstitial lung disease being the highest.

3.3. Factors influencing satisfaction

Table 2 presents the results of multivariate linear regression used to determine the factors influencing patient satisfaction with medications. The results showed that in the effectiveness domain, patient satisfaction was positively associated with junior high

TABLE 1 Characteristics of the patients.

Characteristics	Total (N = 3,435)
Age (years), mean (SD)	67.10 (13.13)
Sex, n (%)	
Male	2,375 (69.1)
Female	1,060 (30.9)
Education background, n (%)	
Primary school and below	1,585 (46.1)
Junior high school	1,052 (30.6)
High school or technical or vocational school	528 (15.4)
Bachelor degree or above	270 (7.9)
Local area, n (%)	
Developed area	2,506 (73.0)
Less developed area	929 (27.0)
Profession, n (%)	
Agriculture, forestry, animal husbandry, fishing, water production personnel	1,400 (40.8)
Professional and technical personnel	204 (5.9)
Production and transportation equipment operators and related personnel	161 (4.7)
Commercial service personnel	144 (4.2)
State organs, Party and mass organizations, enterprises, institutions;	280 (8.2)
Medical and health related personnel;	103 (3.0)
Others	1,143 (33.2)
Place of residence, n (%)	
Urban area	1,318 (38.4)
Rural area	2,117 (61.6)
Smoking status, n (%)	
Be smoking	620 (18.0)
Previous smoking	1,420 (41.4)
Never smoked	1,395 (40.6)
Patients with a single respiratory disease	
COPD	1,862
Asthma	204
Pulmonary arterial hypertension	21
Interstitial lung disease	61
Sleep apnea syndrome	91
Branch expansion	248
Pneumoconiosis	79
Other	271

school ($p = 0.001$), high school/junior high school/vocational school ($p = 0.009$), and university college/bachelor's degree and above ($p = 0.007$), patient satisfaction was also positively associated with personnel in state agencies, party organizations, enterprises, and institutions ($p = 0.024$) and health care-related practitioners
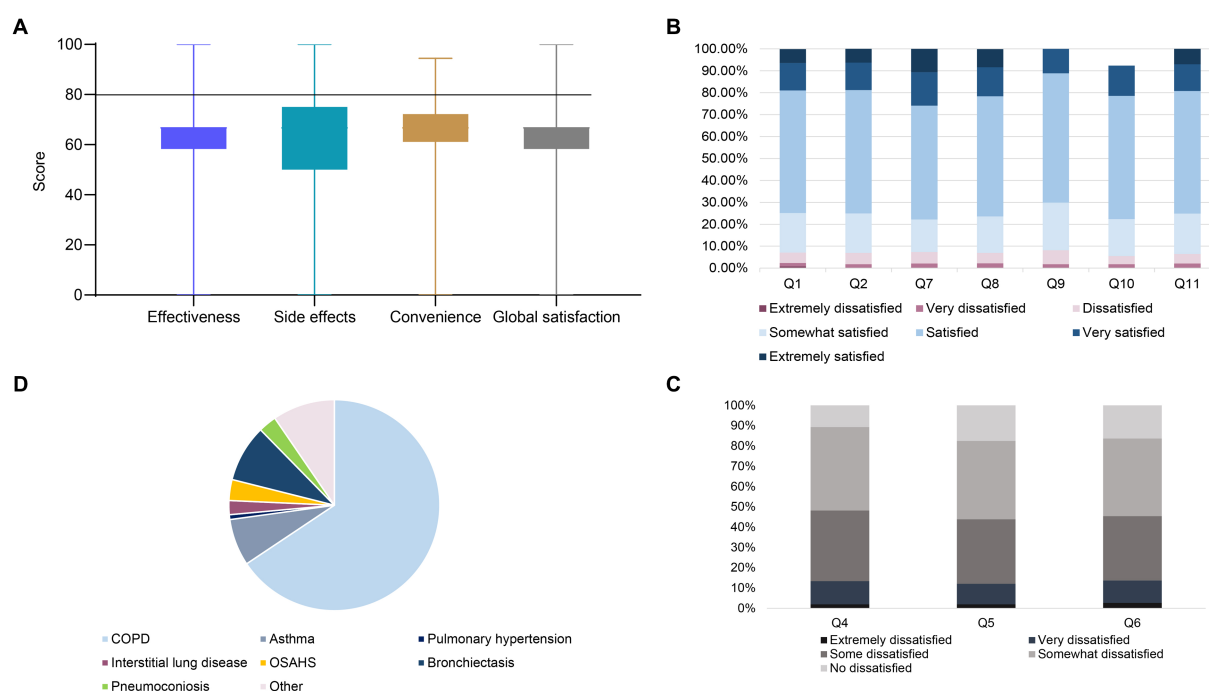
FIGURE 2
(A) Boxplots for treatment satisfaction evaluated by the TSQM-II. **(B)** Stacked bar chart distribution of responses of patients with chronic respiratory disease to TSQM-II questionnaire items in the domains of effectiveness (Q1−Q2), convenience (Q7−Q9) and global satisfaction (Q10−Q11), with answers ranging from extremely dissatisfied (dark pink) to extremely satisfied (blue) on a scale of 7. Q1 indicates "ability to prevent or treat," Q2 indicates "relief of symptoms," Q7 indicates "ease of medication," Q8 indicates "ease of when to take medication," Q9 indicates "frequency of medication/medication"; Q10 indicates "more benefits than disadvantages of medication," and Q11 indicates "satisfaction considering everything." **(C)** The stacked bar chart shows the distribution of the responses of patients with chronic respiratory diseases to the side effect domains of the TSQM-II questionnaire on a 5-point scale from extremely dissatisfied (black) to not dissatisfied (gray). Q5 means "side effects of thinking ability (e.g., ability to think clearly, stay awake)"; Q6 means "side effects of emotions or moods (e.g., anxiety, fear, sadness, irritation)." **(D)** The pie chart shows the distribution of patients with a single chronic respiratory disease condition.

($p < 0.0001$) occupation was positively correlated, and patient satisfaction was positively correlated with never having smoked ($p = 0.001$). In the side effects domain, age was positively associated with patient satisfaction ($p = 0.006$) and patient satisfaction was positively associated with junior high school education ($p < 0.0001$). In the convenience domain, junior high school education ($p = 0.002$) and never having smoked ($p = 0.001$) were positively correlated with patient satisfaction, in addition, patient satisfaction was also positively correlated with the occupation of personnel in state agencies, party organizations, enterprises, and institutions ($p = 0.036$) and health care-related practitioners ($p < 0.0001$). In the area of global satisfaction, patient satisfaction was positively correlated with junior high school education ($p < 0.0009$), patient satisfaction was also positively correlated with personnel in state agencies, party organizations, enterprises, and institutions ($p = 0.005$) and health care-related practitioners ($p < 0.0001$) occupation, and finally previous smoking ($p = 0.04$) and never smoking ($p = 0.001$) were positively correlated with patient satisfaction was positively correlated.

Table 3 presents the results of multivariate linear regression used to determine the factors influencing COPD patients' satisfaction with their medications. The results showed that in the effectiveness domain, patient satisfaction was positively associated with junior high school ($p = 0.011$) and high school/secondary/

vocational school ($p = 0.001$) education, patient satisfaction was also positively associated with other occupations ($p = 0.003$), patient satisfaction was negatively associated with CAT score ($p < 0.0001$), and patient satisfaction was positively associated with acute exacerbations 1–3 times ($p = 0.002$), furthermore, patient satisfaction was positively correlated with home oxygen therapy time ($p < 0.005$), however, patient satisfaction was negatively correlated with home non-invasive ventilation time ($p < 0.005$). In the area of side effects, side effects were reported by 17.5% of COPD patients, patient satisfaction was positively associated with mMRC score ($p < 0.0001$). But patient satisfaction was negatively associated with CAT score ($p < 0.0001$) and home non-invasive ventilation time ($p < 0.05$). In the convenience domain, patient satisfaction was positively correlated with junior high school ($p = 0.006$), high school/secondary/vocational school ($p = 0.032$) education, in addition, patient satisfaction was positively correlated with never smoked ($p = 0.027$), patient satisfaction was negatively correlated with CAT score ($p < 0.0001$) and home non-invasive ventilation time ($p < 0.05$). In the area of global satisfaction, patient satisfaction was positively correlated with junior high school ($p = 0.011$), in addition, patient satisfaction was negatively correlated with professional and technical personnel ($p = 0.036$), and finally patient satisfaction was negatively correlated with CAT score ($p < 0.0001$).
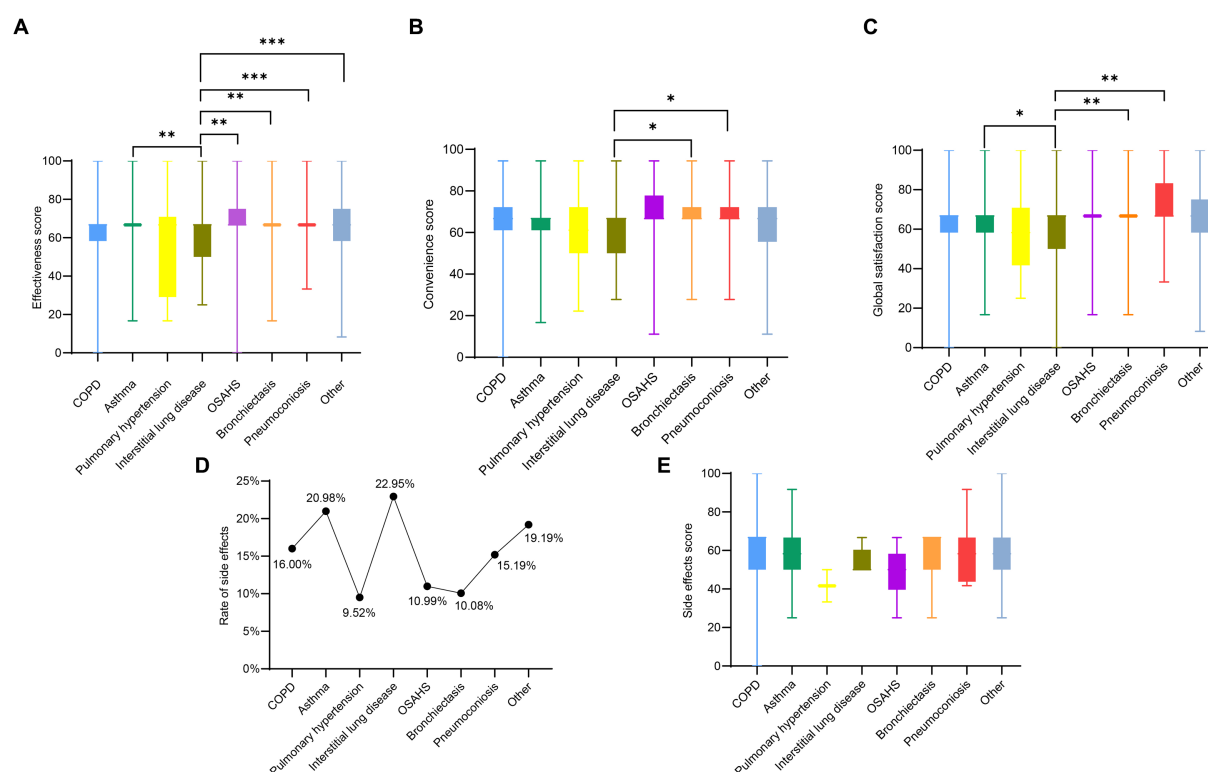
FIGURE 3
Panels **(A–E)** are the effectiveness domain score, convenience domain score, global satisfaction domain score, side effect rate, and side effect domain score for patients with a single chronic respiratory disease, respectively. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

4. Discussion

In this multicenter cross-sectional study, we looked at medication satisfaction and its associated factors in older adult patients with chronic respiratory disease in different regions of Hunan Province, China. This focus on the older adult population is particularly relevant in the context of public health, as this demographic group often faces unique challenges related to their health and well-being. Understanding medication satisfaction among older adults is crucial for improving their overall health outcomes and ensuring effective management of chronic respiratory conditions. By investigating medication satisfaction in this specific population, we gain valuable insights into the actual utilization of medications in managing chronic respiratory disease and the level of adherence among older adult patients. Older adults often require multiple medications for various health conditions, and factors such as polypharmacy, cognitive impairment, and mobility limitations can affect their ability to adhere to prescribed medications. Recognizing and addressing these factors is essential for promoting the safe and effective use of medications among the older adult population.

In this study, the current satisfaction of older adult patients with chronic respiratory disease with the medications they use was first described, specifically demonstrated in four domains: effectiveness, side effects, convenience, and overall satisfaction. With a good treatment satisfaction score of greater than or equal to 80, only 15.9% of patients scored above 80 in the effectiveness domain, while the values in the convenience and overall satisfaction domains were 11.6% and 16.5%, respectively. The effectiveness domain included two dimensions of satisfaction—the drug's ability to prevent treatment and the ability to

relieve symptoms. This information could be used to improve the production of drugs or the selection of medications prescribed by clinicians in the future. For instance, inhalation therapy was found to be a more effective treatment option for COPD and asthma patients as it has easier access to the bronchial and alveolar systems and requires a lower dosage compared to oral or parenteral therapy (24). Inhalation therapy has the advantage of easier access to the alveolar system and lower dose compared to oral or parenteral therapy, but poor adherence due to inadequate patient inhaler technology affects disease management (25, 26), which highlights the need for further improvements in drug use by drug manufacturers. The study also revealed that a significant proportion of patients who reported side effects were dissatisfied with their ability to work physically, emotionally, and mentally with the medication used. These aspects can significantly impact the older adult population's willingness and ability to continue their prescribed treatment regimens. Understanding these limitations and tailoring interventions to address them can help improve medication efficacy, patient adherence, and overall health outcomes in this vulnerable population. Results of a multiple linear regression analysis for overall chronic respiratory disease patients showed that education was an influential factor in patient satisfaction scores, while medication satisfaction was higher among patients in health care-related occupations. In addition, a noteworthy point is that medication satisfaction was higher among patients who had never smoked, smoking being the most prevalent risk factor for chronic respiratory disease worldwide (2), and further education on smoking cessation is needed in the future.

In addition, classification comparison showed that patients with interstitial pulmonary disease had lower satisfaction with drugs and higher reporting rate of side effects than patients with other diseases.

TABLE 2 Factors influencing medication satisfaction, based on TSQM.

	Effectiveness		Side effect		Convenience		Global satisfaction	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Age (years)	−0.014	0.548	0.202	0.006	−0.028	0.204	−0.036	0.117
Male (Ref. female)	--	--	--	--	--	--	−0.005	0.995
Education background (Ref. primary school and below)								
Junior high school	2.209	0.001	7.373	<0.0001	1.878	0.002	1.638	0.009
High school or technical or vocational school	1.118	0.009	2.129	0.083	0.669	0.092	0.467	0.260
Bachelor degree or above	1.186	0.007	−0.326	0.784	0.702	0.085	0.349	0.413
Local Area (Ref. less developed area)								
Developed area	0.756	0.215	--	--	−0.729	0.197	--	--
Profession (Ref. agriculture, forestry, animal husbandry, fishing, water production personnel)								
A	−0.728	0.548	--	--	1.229	0.274	1.601	0.174
B	−0.559	0.391	--	--	0.159	0.793	0.086	0.892
C	0.283	0.303	--	--	0.438	0.085	0.290	0.279
D	0.806	0.024	--	--	0.695	0.036	0.983	0.005
E	0.415	<0.0001	--	--	0.387	<0.0001	0.405	<0.0001
F	−0.728	0.548	--	--	1.229	0.274	1.601	0.174
Smoking status (Ref. be smoking)								
Previous smoking	1.488	0.050	--	--	1.233	0.079	1.514	0.040
Never smoked	1.257	0.001	--	--	1.153	0.001	1.504	0.001

A, Professional and technical personnel; B, Production and transportation equipment operators and related personnel; C, Commercial service personnel; D, State organs, Party and mass organizations, enterprises, institutions; E, Medical and health related personnel; F, Others.

This finding is consistent with the current situation, as there is a shortage of specific drugs available for treating interstitial lung disease. The use of "all-gold oil" hormone drugs is only effective for certain types of interstitial lung disease, and in most cases, the use of hormones is not effective and has noticeable side effects (27). However, the current specific drugs such as "Pirfenidone" and "Nintedanib" are not specific drugs in the clinical sense. Their effectiveness is only for some types of patients with interstitial lung disease, and the patients with mild to moderate disease need to be satisfied (28). Therefore, patients with interstitial lung disease face particular challenges, and the current drug options have limited effectiveness and significant side effects. The development of specific drugs for interstitial lung disease requires further research to address this critical medical need.

This study also focused on the current status and factors influencing medication satisfaction in COPD patients, where the treatment strategy is known to control inflammation at the source, stop disease progression, and treat symptoms caused by airway alveolar destruction. Therefore, COPD treatment drugs are also divided into two categories: anti-inflammatory drugs for causal treatment and

bronchodilators for symptomatic treatment (29). The study conducted multiple linear regression analysis and identified several factors that influenced patients' medication satisfaction scores. The findings indicated that patients' education background, profession, and history of acute exacerbations were influential factors in determining medication satisfaction. The study also highlighted the role of patient disease severity, as measured by the COPD Assessment Test (CAT) score, in determining medication satisfaction. The results showed that patients with higher CAT scores were less satisfied with their medication, suggesting that current symptoms influence medication satisfaction, which could in turn affect patient adherence to treatment. The study also found that factors related to the use of home oxygen therapy was associated with medication satisfaction scores. Home oxygen therapy was found to be a good complement to patients' medication, and it improved their medication satisfaction. These findings provide valuable insights into the factors that affect medication satisfaction in older adult patients. Healthcare providers can use this information to develop tailored interventions to improve medication satisfaction and, consequently, patient adherence to treatment.

TABLE 3 Influencing factors of medication satisfaction of COPD patients, based on TSQM.

	Effectiveness		Side effect		Convenience		Global satisfaction	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Education background (Ref. primary school and below)								
Junior high school	1.779	0.011	--	--	3.008	0.006	2.773	0.011
High school or technical or vocational school	3.262	0.001	--	--	3.353	0.032	2.890	0.064
Bachelor degree or above	2.680	0.141	--	--	−3.596	0.203	−3.358	0.235
Profession (Ref. agriculture, forestry, animal husbandry, fishing, water production personnel)								
A	−1.969	0.181	--	--	−4.190	0.066	−4.790	0.036
B	−1.389	0.330	--	--	−3.855	0.080	−3.573	0.105
C	−0.456	0.785	--	--	−1.824	0.480	−1.688	0.513
D	1.305	0.291	--	--	0.021	0.991	−0.239	0.901
E	5.261	0.096	--	--	3.341	0.497	2.940	0.550
F	2.062	0.003	--	--	−1.192	0.273	−1.270	0.242
Place of residence (Ref. rural area)								
Urban area	--	--	−1.722	0.084	--	--	--	--
Smoking status (Ref. be smoking)								
Previous smoking	--	--	--	--	2.041	0.114	1.502	0.243
Never smoked	--	--	--	--	3.070	0.027	2.250	0.107
CAT score	−0.357	<0.0001	−0.511	<0.0001	−0.538	<0.0001	−0.516	<0.0001
mMRC score	0.002	0.995	1.272	0.013	0.941	0.058	0.909	0.067
Total number of acute exacerbations in the past 1 year (Ref. zero)								
1 to 3	2.490	0.002	−0.614	0.638	--	--	--	--
≥3	−1.093	0.215	−0.883	0.565	--	--	--	--
Total number of severe acute exacerbations in the past 1 year (Ref. zero)								
1			1.464	0.382			1.411	0.348
≥2			−2.639	0.118			−2.890	0.053
Home oxygen therapy time [hours/day (%)] (Ref. zero)								
0 to 4	3.093	0.003	2.470	0.122	--	--	--	--
4 to 8	3.968	<0.0001	−2.286	0.111	--	--	--	--
>8	3.997	<0.0001	1.017	0.517	--	--	--	--
Home non-invasive ventilation time[hours/day (%)] (Ref. zero)								
0 to 4	−5.088	<0.0001	−5.797	0.005	−5.618	0.005	--	--
>4	−3.438	0.001	−4.609	0.005	−5.860	<0.0001	--	--

A, Professional and technical personnel; B, Production and transportation equipment operators and related personnel; C, Commercial service personnel; D, State organs, Party and mass organizations, enterprises, institutions; E, Medical and health related personnel; F, Others.

This study has some limitations. It is an observational study, and in addition the generalization and generalization of the results may be limited because it is not a national study and there may be differences between provinces. In addition, there may be some potential selection bias as participants were limited to hospitalized patients. Cross-sectional findings cannot draw conclusions about

causality, and further research is warranted to explore causality. Patient selection was based on convenience (leading to potential selection bias) and willingness to complete time-consuming patient-reported outcome (PRO) questionnaires, all of which have inherent response and assessment biases. And patients may not want to express dissatisfaction with their medication regimen to their healthcare provider, which could lead to an overestimation of satisfaction rates.

5. Conclusion

Multivariate analysis showed that age, education background, profession, and smoking status were independently associated with patient satisfaction. Satisfaction with medication for interstitial lung disease was lower than for other diseases at the disease-specific level. Multivariate analysis for COPD showed that education background, profession, CAT score, number of acute exacerbations and home oxygen therapy time and home non-invasive ventilation time were independently associated with patient satisfaction. Therefore, the findings of this study have the potential to provide valuable guidance for both drug manufacturers and clinicians. By reflecting the specifics of patient satisfaction with medication and considering the related influencing factors, drug manufacturers can design medications that better meet the needs and preferences of the older adult population. Clinicians, on the other hand, can utilize this information to optimize medication prescribing practices, enhance patient education and counseling, and develop strategies to improve patient adherence to medication regimens. Ultimately, such improvements can contribute to better health outcomes and quality of life for older adult individuals with chronic respiratory disease.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Clinical Trial and Ethics Committee of the Second Xiangya Hospital of Central South University (Registration number: LYF2021012). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JW, WM, HZ, YM, and YC: conception and design. JW: interpretation of data, statistical analysis, and manuscript writing. YM and YC: revision of manuscript and administrative, technical, or material support. 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.2023.1168249/full#supplementary-material

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Social networks and the mental health among Chinese older adults: the mediating role of loneliness and moderating role of Internet use

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Background: Although a large body of research suggests that social networks from family and friends are important factors in protecting the mental health of older adults, we know little about the mediating and moderating mechanisms behind this relationship. Using China as an example, this study aims to investigate a comprehensive model that includes social networks, loneliness, Internet use, and mental health outcomes in the older population.

Methods: We analyzed data from 7,648 Chinese older people over 60 using the 2018 CLASS survey. We studied how various social networks affect their mental health. Using SPSS's PROCESS macro, we first employed descriptive statistics to examine the characteristics of the participants and calculate the correlations of core variables. Then, we assessed whether loneliness mediated this relationship and tested the moderated mediation effect of Internet use. Our findings shed light on these complex dynamics.

Results: The statistics indicate a positive correlation between social networks and mental health. Furthermore, mediation models revealed that loneliness moderates the relationship between social networks and mental health. In addition, moderated mediation models revealed that Internet use played a distinct function in the family networks model compared to the friend networks model. Internet use moderates explicitly the effects of family networks on loneliness and friend networks on mental health.

Conclusion: The findings emphasize the importance of differentiating the types of social networks to understand their impact on older adults well-being, encouraging policymakers, medical professionals, and families to adopt more targeted approaches when devising policy interventions and medical strategies, especially for older individuals with insufficient social support. Additionally, we urge governments to recognize the varying types of social networks among older populations and harness the protective effects of Internet technology on their well-being within a digital society.

KEYWORDS

social networks, mental health, loneliness, Internet use, older adults

1. Introduction

In recent years, population aging, mobility, and the Internet wave have been happening simultaneously in China (1–3). Since China entered the aging society in 2000, the speed of aging has been accelerating, and the scale of the older adult has been expanding. As a result, China has become the country with the largest older adults population in the world (2). Data from the National Bureau of Statistics show that by the end of 2022, the number of older adults aged 60 and above in China has reached 280 million, accounting for 19.8% of the total population. The older population tends to be more likely to face problems with their health than other age groups, and with mental health being an integral part of older people's health (4), it is vital to understand how to maintain and improve the mental health of older adults.

Social networks are an important factor in maintaining and improving the mental health of older adults (5, 6). Social networks mainly include family and friend networks, and different types of networks play different roles in protecting older adults' mental health (7). In China, blood ties are of great significance, and family networks in general, especially parent–child networks, are one of the most critical resources in the lives of older adults and the primary source of support for more aging parents (8). Thus, for older Chinese adults, the protective effect of family networks may be more robust, but it needs to be verified. According to social support theory, the protection of social networks for older adults' mental health includes a main effect and a buffer effect. Some studies have shown that older adults' social networks protect their mental health by reducing loneliness (9), which suggests that loneliness may moderate the relationship between social networks and older people's mental health.

However, the social networks of older adults are under threat due to the increased mobility of the population in China's modernization process. On the one hand, the outflow of young people and the retention of older people have disrupted older people's family networks (10). On the other hand, the older adult may follow their children in migration and lose contact with their friends. Consequently, an increasing number of Chinese older adults face social isolation, threatening their mental health (11). Although impaired social networks may increase the risk of depression in older adults either directly or through increased loneliness, it appears that not all older adults feel lonely and suffer from depression when faced with an inadequate social network (12). According to the risk and resilience framework (13), this difference may be due to protective factors.

Along with the rise of the Internet wave in China, the number of older Internet users is increasing, with 42% of Chinese older adults using the Internet in 2020 (2). Given the increasing influence of the Internet, it is necessary to explore the impact of Internet use on the mental health of older adults. First, research has found that higher Internet use complements interpersonal contact, engagement, and community commitment. Thus, Internet use may be protective when traditional social networks are inadequate (2, 14). Second, online tools are also associated with perceived loneliness in older adults. The Internet can distract older adults from the experience of loneliness and reduce life stress by pulling them into the virtual world (15). Therefore, it is reasonable to assume that Internet use can moderate the direct and indirect links between social networks and older adults' mental health.

In summary, while the existing literature indicates diverse associations between social networks, loneliness, mental health, and Internet use among older adults (16, 17), two critical research gaps remain unaddressed. First, fewer existing studies have delved into the heterogeneity of how different social networks affect mental health in older adults. Secondly, prevailing research has predominantly focused on examining the direct effects of the Internet on older people's mental health (1, 18), overlooking the potential moderating role of the Internet in influencing the direct and indirect ramifications of social networks on mental health. In this study, we propose a moderated mediation model, hypothesizing that different types of social networks are associated with mental health among Chinese older adults, with loneliness playing a mediating role. It further posits disparities in these associations. Additionally, the study examines how Internet use moderates these direct and indirect relationships. By offering a more detailed analysis of the mechanisms through which social networks impact the mental health of older adults in the Internet era, this research aims to provide a theoretical foundation for guiding older adults' use of the Internet and protecting their mental health.

1.1. The Main and mediating pathways

Social networks are an available resource for people to access various types of support (19, 20). Social support theory states that social networks can protect individuals' physical and psychological health through direct and buffering effects (21). At the same time, many empirical studies have shown that social networks are closely related to the mental health of individuals; social networks play a protective role in the mental health of individuals, especially older adults (5, 22).

Social networks change over time and throughout an individual's life course. However, there is no consensus on whether social networks change in old age compared to other age groups and their impact on mental health. One view is that older adults are more likely to have reduced social networks due to the stressful events they are likely to experience in old age, including widowhood, retirement, and illness (23) and that such reduced social networks may leave older adults in a state of social isolation and impair their mental health (24). Other studies have found that social networks remain stable in old age. For older adults, the quality of social networks is more important than quantity, and such long-lasting social relationships protect the mental health of older adults (9).

Social networks are multi-dimensional. According to the social convoy model theory, the two most important social networks for older adults are family and friend networks (19, 25). Family networks, consisting mainly of spouses and children, are located in the inner circle, and these networks are innate and determined by blood ties. Older adults have very stable relationships with these family members. Friend networks, formed by acquaintances, colleagues, and neighbors, are located in the outer circle (26), and friend networks rely on interactions between individuals and are relatively less stable (27).

There may be differences in the relationship between family and friend networks and older adults' mental health. Socioemotional selectivity theory (SST) is the dominant theory in the emotional and social aging field, which can help us understand the significance of different social networks for older adults (28, 29). According to the theory, as people age, their motivational orientations shift as they

perceive time to be limited. The perception of limited time activates goals related to emotional significance and influences motivational preferences. Older adults seek more emotion and meaning than younger people and particularly value family members who play an essential role in their lives. In China, a similar theory has been proposed called "Cha Xu Ge Ju" (30). This theory suggests that in China, blood ties are important, and social networks are centered on the individual, followed by immediate family, other relatives, neighborhood, and friends, with the further away from the individual, the lower the importance.

Based on the above theoretical and literature analysis, we propose hypothesis 1:

> *Hypothesis 1*: There is a positive association between social networks and the mental health of older Chinese people. Compared to friend networks, The correlation is more robust for family networks.

The pathways through which social network dimensions influence the mental health of older adults remain unknown. Research suggests that loneliness negatively predicts mental health. Individuals experiencing loneliness tend to have poorer mental health (16, 31, 32). Loneliness is a subjective feeling often characterized by a sense of isolation, a lack of social belonging, and an unpleasant intimate experience (33, 34). It has also been conceptualized as distress arising from discrepancies between an individual's desired and actual social relationships (35). Among the factors influencing loneliness, the role of social networks is significant. Inadequate social networks positively predict feelings of loneliness (5, 36). Kovacs et al. (37) found that individuals with less than five close confidants during a crisis were likelier to report enhanced loneliness (37). The above studies suggest that loneliness may mediate the relationship between social networks and mental health and act as a mental health risk factor in older adults.

Some studies have supported the social networks→loneliness→mental health pathway. Qian's (38) study found that for people living with HIV, loneliness mediates the decline in mental health due to social support (38). Park et al. (9) studied 209 older Korean adults in Central Texas. They found that older adults were at an increased risk of poor mental health when experiencing a severe lack of social connections, also known as social isolation. Further mechanistic studies revealed that loneliness mediated the relationship between social isolation and depressive symptoms (9). However, it remains unclear whether loneliness also mediates the relationship between family/friend networks and mental health among older Chinese individuals.

Based on the above theoretical and literature analysis, we propose hypothesis 2:

> *Hypothesis 2*: Loneliness mediates the relationship between family/friend networks and older adults' mental health.

1.2. The moderating role of Internet use

The widespread availability of Internet installations in China coincides with the increasing trend of "Netizens" aged 60 and older. Internet use has become an indispensable lifestyle for the older Chinese and is crucial for their healthy psychological development (39). The emergence and widespread use of the Internet have led scholars to concentrate on this new element. A systematic review has determined that Internet use can be a protective factor during an individual's positive development (40). Theoretically, Internet use can free older people from stigma and limited Internal ability as a new form of social engagement (41, 42). Many studies have revealed that Internet use has a significant impact on reducing loneliness and depression, as well as on improving social support among older people (1).

From social capital theory, social capital refers broadly to the resources that emerge from one's social ties (43, 44) and play a significant role in determining self-rated health, healthy behavior, and mental health (45). Studies have found that Internet use buffers the negative link between age and social capital, acting as a priceless tool for preserving existing friendships, enhancing familial bonds, and fostering virtual connections (46). Bonding and bridging social capital are the two main components of social capital (44). On the one hand, older adults who have been using the Internet for a long time can break time and space restrictions and use Internet devices to maintain close contact with family and friends (known as "bonding social capital"), which enables them to reach out for assistance more easily and quickly. Therefore, Internet use by senior individuals is more conducive to the protective effect of their social networks on mental health, especially for older people with disabilities (47). On the other hand, virtual networks facilitate the expansion and diversification of social ties between various generations and social groups (48). Using the Internet broadens older people's exposure to more resources. It helps them meet more people from varied backgrounds (known as "bridging social capital") (49, 50), which will effectively mitigate the negative effects of low family/friend networks. The benefits mentioned above of Internet use might increase the positive impact and reduce the negative impact of social networks on older people.

Moreover, Internet use can also impact the role of loneliness as a mechanism between social networks and mental health, and a wide range of Internet use interventions have been tested to reduce loneliness among older adults (51). From the definition of loneliness, researchers have deduced that three coping strategies can alleviate loneliness and its negative effects: building supportive networks, lowering standards, and putting loneliness into perspective (15). First, the Internet has shown some potential to benefit older adults regarding their supportive networks by enhancing personality traits like self-confidence, perceived self-efficacy, and perceived control (52) and reducing the adverse effects of age-related stereotypes (53). Previous studies have found that even with the same family and friend networks, increased Internet use supplements interpersonal contact, engagement, and community commitment, providing individuals access to more supportive networking and potentially reducing feelings of loneliness (17). Secondly, using Internet technologies is connected with putting loneliness into perspective among older adults. The Internet could distract older adults from their loneliness experience and lower perceived life stress by pulling them into virtual worlds (54). Consequently, higher Internet use may also mitigate the negative effects of loneliness. Therefore, Internet use may play a risk-buffer role and alleviate the adverse effects of loneliness on the mental health of older adults. Based on the findings of previous research, We formulate hypothesis 3:

Hypothesis 3: Internet use moderated direct and indirect relationships between family/friend networks and older adults' mental health. Specifically, Internet use would buffer the direct effect of family/friend networks on mental health (Hypothesis 3a) and buffer the mediating influence of loneliness on the effect of family/friend networks on mental health (Hypothesis 3b).

This study's primary objectives were to explore the relationships between Social networks (SN) and Mental health (MH) and to test whether the influence of SN on MH is mediated by loneliness (LO) and moderated by Internet use (IU). Based on the results of previous studies, Figure 1 illustrates three hypotheses.

2. Materials and methods

2.1. Data source

The data used in this study are from the 2018 waves of China Longitudinal Aging Social Survey (CLASS). CLASS is a nationally representative panel study that has followed adults aged 60 and above in China at 2-year intervals since 2014(data and documentation available at http://class.ruc.edu.cn). CLASS aims to collect plentiful information about health measures, family relationships, and social participation from approximately 11,000 Chinese respondents over 60 using a stratified multi-stage probability sampling method. In 2018, we surveyed 11,418 participants; only those who replied properly to at least three of the cognitive questions in the CLASS survey were eligible to proceed to the mental health questions. Consequently, the respondents' cognitive abilities influenced the data for key variables such as mental health and loneliness, resulting in many missing values ($N = 2,184$). Additionally, due to the higher sensitivity of the personal income question, 1,405 (12.3%) respondents selected options such as "do not know" or "do not want to answer." Furthermore, the gender distribution (male, 50.34%) is almost identical to that of the full sample (male, 50.24%), and the mean age of the final sample (Mage = 71.2) is approximately the same as that of the full sample (Mage = 71.4), which indicates a good representation. After excluding observations with missing values for the variable we are interested in, 7,648 valid observations were finally included in the analysis. The final samples consisted of 3,850 males (Mage = 71.13, SDage = 7.15) and 3,798 females (Mage = 71.29, SDage = 7.37).
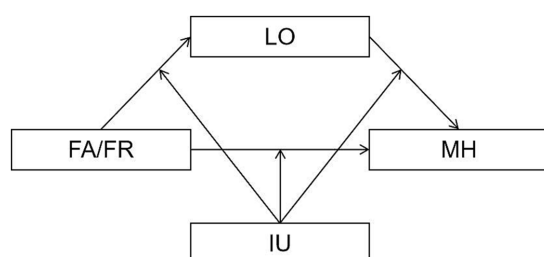
FIGURE 1
The proposed mediated moderation model. FA, Family networks; FR, Friend networks; LO, loneliness; MH, Mental health.

2.2. Variable design

2.2.1. Explained variables

The dependent variable in this study was mental health. The 9-item Depression Scale (CES-D) was used to measure mental health according to the commonly used measures of mental health (55). We asked the participants about the frequency of depressive symptoms during the past week. We assessed responses to each question using a 3-point Likert scale, where "1" means "hardly ever or never" and "3" means "often." We reverse-recorded six negative items and summed the result after reverse coding as a continuous variable, with higher values indicating better mental health. This method has been validated in previous studies worldwide (56, 57), with Cronbach's alpha coefficient of the scale being 0.71.

2.2.2. Independent variables

The independent variable was the social networks of older adults, divided into family and friend networks. We used the Lubben Social Networks Scale (LSNS), a reliable and valid instrument to measure the quality, intimacy, and frequency of participants' social relationships (58) to measure the social networks of older Chinese adults (59). The scale comprises six questions:(1) How many relatives/friends do you see or talk to at least once a month? (2) How many relatives/friends do you feel more comfortable talking to about personal matters? (3) How many relatives/friends do you feel close enough to ask for help? We coded responses to each question as (0 = none, 1 = 1 person, 2 = 2 persons, 3 = 3 or 4 persons, 4 = 5 to 8 persons, and 5 = 9 or more persons). The final scores for both family and friend networks were on a scale of 0–15. Higher scores mean that older people have closer family and friend relationships. The Cronbach's coefficient was 0.82 for the family network scale and 0.84 for the friend network scale.

2.2.3. Mediating variables

The mediating variable was loneliness in this study. We use the UCLA loneliness scale to assess loneliness. The scale comprises three questions: (1) How frequently do you experience a lack of social interaction? (2) How frequently do you feel disconnected from the individuals around you? and (3) How frequently do you feel alienated from others? A 3-point Likert scale, with "1" meaning "rarely" and "3" meaning "most of the time," was used to evaluate each response in every case. Responses were assessed on a 5-point Likert scale, with "1" indicating "never," "2" indicating "rarely," "3" indicating "sometimes," "4" indicating "often," and "5" indicating "always." The validity and reliability of this scale have been tested in a previous study (60). Reliability analyzes revealed that Cronbach's alpha coefficient of the scale was 0.77.

2.2.4. Moderating variables

The moderating variable in this study was Internet use. Following previous research, We use a signaling question to measure Internet use ("How frequently do you access the Internet?"). This measurement method has been widely used in studies worldwide as a quick measure of older adults Internet use (18, 61).

2.2.5. Control variables

Literature reveals that the mental health of older adults has numerous correlations and varies by socio-demographic background, health status, and social environment (30, 62). To control potential effects, We use socio-demographic characteristics as control factors,

including age (continuous variable), gender (male=1), living area (urban=1), marital status (widowed=1), educational level (0=less than elementary; 1=elementary; 2=secondary; 3=college and above), self-rated health (poor to excellent), functional health (ADL), income (continuous variable), and the number of children (continuous variable).

2.3. Analytical strategy

First, we used descriptive statistics to examine the characteristics of the participants and calculate the correlations of core variables. Second, we used bootstrapping to test whether loneliness mediates the effect of social networks on older adults' mental health. Finally, we added Internet use to the mediation model to test the moderated mediation effect.

We use IBM SPSS Statistics (version 24.0) to conduct statistical analysis. We use the PROCESS macro (version 4.1) to analyze the mediating role of loneliness and the moderating role of Internet use. The bootstrapping method produces 95% bias-corrected confidence intervals (CIs) for these effects from 5,000 bootstraps resamples. CIs (95%) without zero indicate a significant effect.

3. Results

3.1. Descriptive statistics

Table 1 shows the socio-demographic characteristics of older adults and the statistics of all variables. The average age of the respondents was 71.21 years; 49.66% were male, 60.33% lived in rural areas, 70.24% had a spouse, and 63.38% were educated below middle school. The average annual income(logged) of the respondents was 8.19 (SD=1.43), the mean score of activity of daily living (ADL) was 6.21 (SD=1.01), the mean score of self-assessed health was 0.68 (SD=0.71). The average family networks scale score was 7.37 (SD=2.78), the average friend networks scale score was 6.41 (SD=3.17), the average loneliness scale score was 4.46 (SD=1.57), the average Internet use score was 1.74 (SD=1.50). The average mental health scale score was 18.73 (SD=2.63).

Table 2 shows the correlations between the main variables. Family networks, friend networks, and loneliness were all significantly associated with the mental health of older adults(r=0.110, $p<0.001$;r=0.113, $p<0.001$; r=−0.489, $p<0.001$), and both family networks and friend networks were significantly associated with loneliness(r=−0.144, $p<0.001$; r=−0.091, $p<0.001$), suggesting the potential role of loneliness in mediating the relationship between different types of social networks, and the mental health of older adults. In addition, Internet use was significantly associated with family networks(r=0.082, $p<0.001$) and friend networks(r=0.118, $p<0.001$) and loneliness(r=−0.134, $p<0.001$) and mental health(r=0.135, $p<0.001$), suggesting a potential role for this variable in modifying the relationship between different types of social loneliness, and mental health in older adults.

3.2. Analysis of primary and mediating effects

To examine the relationship between family networks, friend networks, and older people's mental health and whether loneliness

TABLE 1 Descriptive statistics.

Variables	Mean	SD	Min	Max
Age	71.21	7.26	60	100
Gender				
Female (*n*, %)	3,850	50.34		
Male (*n*, %)	3,798	49.66		
Residence				
Urban (*n*, %)	3,034	39.67		
Rural (*n*, %)	4,614	60.33		
Marriage				
Married (*n*, %)	5,372	70.24		
Unpartnered (*n*, %)	2,276	29.76		
Education				
Lower than middle school (*n*, %)	4,847	63.38		
Middle school and above (*n*, %)	2,801	36.62		
Income (logged)	8.19	1.43	4.09	16.12
ADL	6.21	1.01	6	18
Self-assessed health	0.68	0.71	0	2
Family networks	7.37	2.78	0	15
Friend networks	6.41	3.17	0	15
Loneliness	4.46	1.57	3	9
Internet use	1.74	1.50	1	5
Mental health	18.73	2.63	9	24

N=7,648, SD, standard deviation.

TABLE 2 Descriptive statistics and correlations of core variables.

	1	2	3	4	5
Family networks	–				
Friend networks	0.647***	–			
Loneliness	−0.144***	−0.091***	–		
Internet use	0.082***	0.118***	−0.134***	–	
Mental health	0.110***	0.113***	−0.489***	0.135***	–
ME	7.37	6.41	4.46	1.74	18.73
SD	2.78	3.17	1.57	1.50	2.63

N=7,648, *p<0.05, **p<0.01, ***p<0.001.

plays a mediating role, we used SPSS 24.0 software, Process Model 4. Table 3 and Figure 2 show the results.

First, the results in Table 3 show that family and friend networks are positively related to the mental health of older adults. The total effect of family networks is 0.086 ($p<0.001$), the total effect of friend networks is 0.063($p<0.001$), and the impact of family networks is greater than that of friend networks. We proved hypothesis 1.

The results in Table 3 and Figure 2 indicate that family networks were positively associated with the mental health of older adults through two pathways. One is the direct effect, where the more robust

TABLE 3 Test results of main and mediating effect analysis.

Model pathways	β	SE	95% CI	
			Lower	Upper
Direct effects				
FA → MH	0.027*	0.009	0.009	0.045
FR → MH	0.036***	0.008	0.020	0.052
Indirect effects				
FA → LO → MH	0.059***	0.005	0.049	0.069
FR → LO → MH	0.027***	0.005	0.018	0.036
FA Total effect	0.086***	0.001	0.066	0.107
FR Total effect	0.063***	0.010	0.045	0.081

$N = 7,648$, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

TABLE 4 The moderated mediation model with loneliness as a mediator and Internet use as a moderator.

Variable	β	SE	95% CI	
			Lower	Upper
Loneliness				
FA × IU	0.010*	0.004	0.002	0.019
FR × IU	0.006	0.004	−0.002	0.014
Mental health				
FA × IU	−0.010	0.012	−0.034	0.014
FR × IU	−0.019***	0.006	−0.030	−0.008
LO × IU(FA)	−0.002	0.007	−0.015	0.011
LO × IU(FR)	−0.012	0.012	−0.036	0.011

$*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

FIGURE 2
The mediating effect of loneliness on family networks/friend networks and mental health, $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

the family networks, the higher the mental health of older adults ($β = 0.027$, $p < 0.05$). One is the indirect effect, in which the family networks negatively affect loneliness ($β = −0.078$, $p < 0.078$), which in turn affects the mental health of older adults ($β = −0.078$, $p < 0.078$), with the direct effect accounting for 31% and the indirect effect accounting for 69% of the total effect. Also, there is a mediating effect of loneliness in the relationship between the friend networks and the mental health of older adults, with the direct effect accounting for 57% and the indirect effect accounting for 43% of the total effect. Hypothesis 2 was confirmed.

3.3. Testing for the moderated mediation

To examine the moderating effects of Internet use on the direct and indirect effects of different types of social networks on the mental health of older adults, we used SPSS 24.0 software, Process Model 59. Table 4 shows the results.

Among the three moderated mediation models of family networks and the mental health of older adults, one model has detected a significant moderating effect (Table 4). The results showed that Internet use significantly regulated the relationship between family networks and loneliness ($β = 0.010$, $SE = 0.004$, $LLCI = 0.002$, $ULCI = 0.019$). Among the three moderated mediation models

between friend networks and older adults mental health, one model also detected a significant moderating effect. The results showed that Internet use significantly moderated the relationship between friend networks and mental health ($β = −0.019$, $SE = 0.006$, $LLCI = −0.030$, $ULCI = −0.008$).

We constructed a moderating effect graph and further analyzed the moderating effect of Internet usage. Figure 3 shows that Internet use moderates the negative correlation between family networks and loneliness. The negative correlation will be weaker when older adults have high levels of Internet use. Figure 4 shows that Internet use moderates a positive correlation between friend networks and the mental health of older adults. The positive correlation will be weaker when older adults have high levels of Internet use.

4. Discussion

In this study, we explored the relationship between different dimensions of social networks, including family and friend networks, and the mental health of older Chinese adults. In addition, we explored the mechanisms by which social networks affect the mental health of older adults through mediation analysis. Finally, we discuss the role that frequency of Internet use plays in the pathways by which social networks influence mental health in older adults. Both family and friend networks were positively associated with older people's mental health in China, with the results indicating that higher-scoring social networks, especially family networks, are a significant component in protecting older people's mental health. Loneliness is an important pathway through which family/friend networks affect older people's mental health. Internet use moderates the indirect mechanism by which family networks affect older people's mental health, and high Internet use frequency weakens the effect of family networks on older people's loneliness. Internet use directly moderates the relationship between friend networks and older people's mental health, and for older people with low friend networks, high Internet use frequency weakens the impairment of low friend networks on mental health.

4.1. Relationship between SN and MH

Overall, our first hypothesis was supported. That is, higher family/friend network scores are associated with higher levels of

The moderating effect of Internet use on the relation between family networks and loneliness.

The moderating effect of Internet use on the relation between friend networks and mental health.
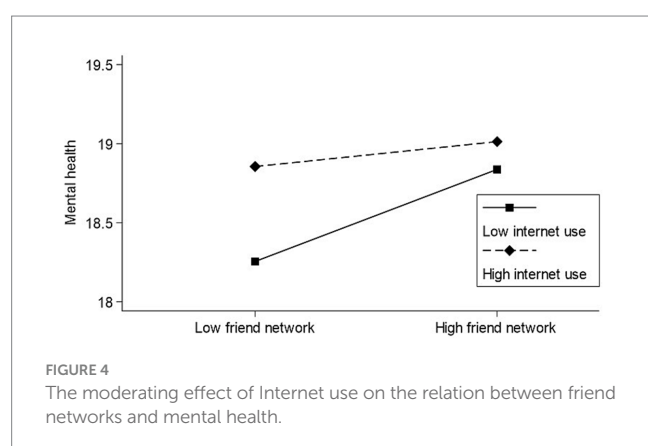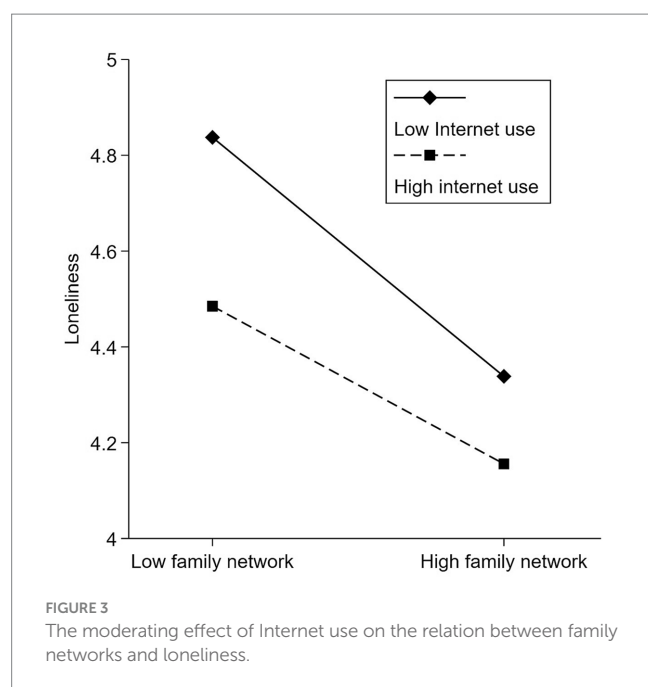
mental health. Similar studies have also demonstrated the association between social networks and mental health (26, 37, 63). However, our findings enrich and go beyond existing studies in two main ways: First, we focus on the 60+ older adults population in China, which is very large, given the aging of the Chinese population (6, 64). However, existing studies still inadequately address older Chinese adults' social networks and mental health. Second, our study distinguished between family networks and friend networks, and the results showed that the relationship between family networks and their mental health was stronger among older Chinese adults than between friend networks. This study found that family networks have a more significant impact on older Chinese adults' mental health than friend networks, consistent with the socioemotional selectivity theory and the Chinese "Cha Xu Ge Ju" theory. According to the socioemotional selectivity theory, older adults prioritize emotionally meaningful relationships, especially those with family members (29). From this perspective, decreasing social relationships in later life is a self-initiated process driven by prioritizing emotionally meaningful relationships over

more extensive social networks (65). This result suggests that the quality of social networks is even more crucial for the social networks of older adults. Family networks, in particular, are vital for protecting the mental health of older adults. According to the "Cha Xu Ge Ju" theory, Chinese social relationships follow a self-centered differential pattern, including family and friend networks. However, these relationships have different statuses and affinity, and family networks, represented by blood ties, tend to be more important to Chinese people (6, 66). These effects suggest that different types of social networks have different utilities in protecting the mental health of Chinese older adults, with family networks being particularly significant.

4.2. The mediating role of LO

Furthermore, the findings suggest that higher-scoring family and friend networks are indirectly associated with mental health by reducing loneliness, in addition to being directly associated with mental health in older adults. Higher scores in family and friend networks may reflect the higher social capital possessed by older adults, and social capital may promote social interaction and participation (34, 38), reducing loneliness and promoting mental health in older adults. Previous studies have found similar findings (9, 63).

Another interesting finding is that in the relationship between family networks and older adults' mental health, the indirect effect dominates, and the direct effect is relatively small, suggesting that family networks mainly affect older adults' mental health by influencing their feelings of loneliness. In contrast, the direct effect dominated the relationship between friend networks and older adults' mental health, suggesting that friend networks are more directly related to older adults' mental health. This finding may echo some previous findings that the structure of social networks is related to loneliness, with social networks divided into close networks (family networks) and non-close networks (friend networks). Having more confidants or very close ties in one's networks is usually associated with lower levels of loneliness (32, 67), while non-close networks, while also associated with lower levels of loneliness, are less protective (37, 68, 69).

Overall, loneliness mediates the relationship between family and friend networks, which verifies hypothesis 2. Also, loneliness is a risk factor for mental health in older adults, and we found that having closer family networks compared to friend networks is vital to reducing loneliness in older adults.

4.3. The moderating role of IU

The use of the Internet has a profound impact on the daily lives of older people, and it can affect their well-being by influencing how easily they can access social support from family and friends. Few studies, however, have examined how family/friend networks and loneliness interact to improve the mental health of older adults. The moderated mediation model found a more complex interaction effect among family/friend networks, loneliness, and mental health, with their relationships varying according to the frequency of Internet use.

These findings are consistent with previous studies (70) showing that elders' participation in virtual worlds is crucial to mental health.

Specifically, the moderating role of the Internet differed in the family and friend networks models. First, the frequency of Internet use moderates the negative relationship between family networks and loneliness, with older adults who used the Internet more frequently showing a weaker relationship than those who used it less frequently. It suggests that Internet use protects, as expected, against increased loneliness due to lower levels of family networks. This buffering effect supports the "stimulus hypothesis" that older people benefit from the social (71) and entertainment functions (72) of the Internet. They have more options for connecting with others (2) and more leisure activities (73). They are less concerned about loneliness in the online community (74), thus reducing the loneliness experience of low family networks. At the same time, this finding also suggests that Internet use protects against loneliness among older adults, even when they have strong family ties. It also fits with previous research highlighting how the older adults use ICTs to enhance their social interactions. This is achieved by overcoming geographical barriers and capitalizing on optimization strategies to augment their opportunities for connectivity (75). However, Internet use did not moderate the direct relationship between family networks and mental health, possibly because low levels of family networks were directly associated with increased depressive symptoms. Internet use could provide older people access to a broader range of individuals from different backgrounds, bringing in more bridging social capital than family/friend networks (76). Thus, Internet use and family networks may affect older people's mental health separately. In future studies, We can further insight into this finding through different qualitative research methods, such as group interviews.

The frequency of Internet use moderated the positive relationship between friend networks and mental health, and this relationship appeared to be weaker for older adults who used the Internet more frequently than for those who used it less frequently. One possible explanation is that the Internet has become a window into the world for older people, increasing the importance of their enjoyment of life and allowing them to learn about and have a more interesting life (64). The Internet also increases their perception of the social capital associated with friends and the likelihood of rekindling previous relationships (e.g., high school friends) (77). Thus, this incremental finding is consistent with previous research showing that the Internet can amplify mental health outcomes through increased friend networks. Nevertheless, unlike the family networks model, Internet use has not significantly changed the relationship between friend networks and loneliness. This result may be explained by the fact that the social relationships of older Chinese people are mainly in a "Cha Xu Ge Ju "model, and their experience of loneliness is more directly related to their family networks. At the same time, older people's friendships are stable, and they are more concerned with the quality than the quantity of their friendships, preferring face-to-face interactions (78, 79). They will only choose communication technology to stay in touch with close companions unless a long-distance relocation event occurs in later life (80). Additionally, Internet use did not moderate the relationship between loneliness and mental health, which may be directly related to loneliness and older people's mental health.

Overall, the Internet moderated the negative relationship between family networks and loneliness and the positive relationship between

friend networks and mental health. The more frequent Internet use predicted a higher level of mental health status, which partially verified Hypothesis 3. Also, the moderating role of the Internet differed in the family and friend networks models. The study found that encouraging online engagement effectively affected older people's social networks, loneliness, and psychological well-being.

4.4. Limitations and implications

In conclusion, social network factors may contribute to a better understanding older Chinese adults' mental health. The cross-sectional research methodology, however, restricted the interpretation of the causal association between social networks, loneliness, and mental health. Also, although this study was analyzed using control variables such as gender and age, future research should consider other confounding factors such as family features and socioeconomic status. These variables may influence the social participation and negative emotions of older adults. In addition, we used retrospective and self-reported measures to assess study variables, which are susceptible to common biases. Future studies should use a longitudinal design and control for possible confounders to determine causal associations and investigate the underlying mechanisms. Despite these limitations, this study is relevant as it suggests specific treatments for older Chinese adults, considering this population's relatively low levels of mental health. Furthermore, an empirical basis for improving mental health levels in the Internet age is proposed using nationally representative data.

In summary, the results of our study have several immediate practical implications for the prevention and intervention of elders' mental health. Firstly, given that social networks negatively predict loneliness and positively predict mental health, increasing the quantity and quality of family and friend networks may be an effective way to improve older people's mental health. Secondly, this study suggests that loneliness may mediate between social networks and older people's mental health. This indicates that identifying and focusing on older adults who experience more loneliness may help us improve the effectiveness of mental health interventions for older adults. Third, our study suggests that the Internet may help protect older adults from the loneliness and depression associated with social support networks. Therefore, encouraging older adults to use more Internet services, experiment with more Internet features, and increase their online capital could reduce loneliness and improve mental health.

More importantly, there are differences in the roles of family and friend networks. Family members are more significant to Chinese older adults and have a greater influence on their mental health. Internet use often weakens the negative relationship between family networks and loneliness while enhancing the positive relationship between friend networks and mental health. According to the findings of this study, policymakers, medical professionals, and families should be aware of the potential effects that might be caused by different types of networks and the various functions that the Internet can perform. Increased awareness could encourage more targeted improvements in policy interventions and medical interventions. It is necessary to focus on older people with inadequate family support, distinguish between different social networks for older people, and maximize the protective role of Internet technology.

5. Conclusion

This study tested a moderated mediation model to examine the psychological factors in the relationship between family/friend networks (FA/FR) and mental health (MH) in older Chinese adults. In short, the research revealed that social networks protected older Chinese adults' mental health and predicted mental health by influencing loneliness (LO). In the family networks model, the effect of social networks on loneliness was buffered by Internet use. In contrast, the effect of friend networks on mental health was buffered by Internet use. These results significantly advance our understanding of older Chinese people's mental health and social networks in the Internet age.

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

HL and JT collected the data and performed the data analyzes, drafted and revised the manuscript. All authors contributed to the article and approved the submitted version.

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Living arrangements, health lifestyles, and health outcomes among Chinese oldest-old

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Background: Prior literature has documented a strong correlation between living arrangements and older adults' health outcomes. However, few studies have explained why this association exists. This study took the health lifestyle theory approach and brought health lifestyles into the link between living arrangements and Chinese oldest-old health outcomes. It examined (1) whether healthy lifestyle behaviors among the oldest-old varied by household contexts and (2) whether the health disparities among the Chinese oldest-old in different household contexts could be partially explained by their healthy lifestyles.

Methods: Using the most recent 2018 data released by the Chinese Longitudinal Healthy Longevity Survey (CLHLS), latent class analysis was applied to identify predominant health lifestyles among the Chinese oldest-old aged 85–105 years. Regression analyses were used to test the mediating effect of health lifestyles.

Results: Three distinct classes representing the health lifestyles of Chinese oldest-old emerged; health lifestyle patterns were found to vary by elders' living arrangements. The respondent's health lifestyles in diverse residential structures served as a mediator which can partially explain the health disparities among the oldest-old.

Conclusion: The results suggested that health lifestyles can serve as a mediator to explain the association between oldest-old living arrangement patterns and their health outcomes. The findings highlighted the importance of family, lifestyles, and cultural contexts to the health of the oldest-old.

KEYWORDS

health lifestyles, living arrangement, latent class analysis, oldest-old, CLHLS

1. Introduction

The linkage between living arrangements and older adults' health and wellbeing has been well-studied in social sciences. Different health outcomes have been considered, including subjective wellbeing, functional health, self-rated health (SRH), and mortality (1, 2). Researchers documented mixed results when studying health differentials of older adults who lived alone and who lived with others. Some found that co-residence created tension which was detrimental to older adults' health. Researchers showed living alone benefited older adults' mental health (3). While others challenged such results by showing co-residence was beneficial to older adults' health (4). Those who lived in institutions were found to have a higher mortality rate (5). Living alone has also been documented to lead to poor health conditions, including depression, cardiovascular disease, and dementia (6, 7). Researchers further emphasized that the beneficial effects of co-residing on older adults' health varied in different family contexts. Those who lived only with a spouse tended to report better health than those who lived with a spouse and children (8). Living with a married son was found to be more beneficial to parents' psychological wellbeing than living with other children in Vietnam; living with a daughter was found to bring greater benefits than living only with a son (9).

Despite many theoretical explanations accounting for the linkage between older adults' living arrangements and their health outcomes, few of them have considered the health lifestyle approach. Recent studies have proved health lifestyles to be an important factor that determines one's physical and overall health outcomes (10–12). Under this proceeding, this article intended to fill the voids of prior literature by bringing health lifestyles into the research scope to detect whether health lifestyles can serve as a mediator linking living arrangements and health outcomes among the Chinese oldest-old. In other words, co-residence or co-residing in various household contexts can lead to different health-enhancing lifestyles, such as an increased involvement in exercise, or a decreased consumption of cigarettes and alcohol, which in turn promotes older adults' health. This analysis focused on the oldest-old, those 85 years and above. This is because there has been growing recognition that the older adult population aged 65 years and older is heterogeneous. The study thus restricted its focus to the oldest-old, a fast-growing population in Chinese society. Relying on the latent analysis strategy, the study used the 2018 wave of the Chinese Longitudinal Health and Longevity Survey (CLHLS), a nationally representative data, to perform the analysis. Findings based on analyzing nationally representative data in China are also valuable to addressing health promotion-related issues among the oldest-old population in other Asian countries. Understanding how health behaviors cluster together among older adults in various household contexts can also help to expand theories of living arrangements and health disparities in general.

2. Literature review

2.1. Living arrangement and its association with Chinese older adults' health

China is a country that has a strong tradition of filial piety and an expectation of sons providing care to older adults; living alone is, therefore, less desirable as compared to Western countries. With drastic social and economic changes, expectations and preferences regarding living arrangements have changed in recent decades, especially in urban areas. The one-child policy and increased female labor force participation have also limited the younger generation's ability to provide care. Chinese society has provided alternate sources of old-age support as well. Some parents would prefer not to live with a married son if the situation allowed. Daughters are just as likely to provide support as sons (13). Thus, there has been a rapid increase in the number of senior households living alone or only with their spouses (14). Even with dramatic changes in Chinese society, traditional family norms have remained. An older adult co-residing with one or more adult children has still been a long-standing and continuing practice and a fundamental way of household structure in China (15). Living with sons has still been prevalent, even if living with daughters has become more desirable and more common (16).

Regarding the association between living arrangements and older adults' health outcomes, although mixed results have been documented in a variety of social contexts, in China, where there is a strong tradition of filial piety and an expectation of sons providing

care to older adults, empirical findings largely corroborated that co-residence had a positive impact on older adults' health. In general, older adults who lived with adult children were found to report better SRH, a lower likelihood of having activity of daily living (ADL) disabilities, and were less likely to feel lonely or depressed (4, 17–19). Scholars also observed that Chinese older adults who lived with family members had greater odds of reporting good quality of sleep and a longer duration of sleep (20). By differentiating the Chinese oldest-old from those who lived with sons and those who lived with daughters, Chen and Short (13) further pointed out that the oldest-old who lived with daughters reported the best emotional health results, and those who lived alone displayed the worst health outcomes. Prior studies also showed that older adults who moved into an institution from living with family faced a greater risk of dying compared to those who continued to live with family members (5).

2.2. Mechanisms linking living arrangements and health

Several mechanisms have been proposed to explain the association between living arrangements and older adults' health outcomes. These theories can be categorized as follows:

2.2.1. Social integration explanation

Scholars contended that co-residence promotes older adults' health because the household provides an important context to individuals for social integration and various dimensions of support. Co-residence with adult children meets the needs of daily care and provides physical and emotional support to older adults. Social support may buffer the harmful physical and mental health effects of exposure to stress and negative social events (21–23). Thus, co-residence promotes elders' health and wellbeing (24, 25).

2.2.2. Filial piety theory

Researchers argued that in societies where there are patrilineal kinship systems, individuals are considered to belong to their father's lineage. Older adults are expected to co-reside with a married son and his wife. Patrilocality is considered a manifestation of filial piety or the moral obligation of children to revere their parents (26). In China, filial piety is a fundamental cultural expectation; going against it by living alone may cause feelings of stress, even guilt, for an elder person. Given that filial piety is the most important cultural ideal in Confucian Asian societies, living with married sons is likely to benefit older adults' health, especially psychological wellbeing (27, 28). Such a beneficial effect is considered independent of intergenerational support (9).

2.2.3. The balance of resources and demands theory

Researchers holding this explanation argued that demands without corresponding resources may lead to poorer health. When resources equal or exceed demands, household relations may benefit or protect health (29, 30). According to this theory, a

person's resources diminish as he or she grows older, which is characterized by a lower physical capacity to do IADL activities; while their demands in terms of requiring assistance and care gradually increase. Evidently, living alone can lead to a resource deficit because there is no social support in the household. The resources available through living with adult children vary according to how much time adult children are available at home and how much care adult children can provide to elder parents. In this sense, households with different living arrangement structures make different demands on individuals and offer different resources too. Thus, older adults who stay in household contexts can balance their resources and demands and are likely to have better health outcomes.

2.2.4. Social conflicts theory

Those who supported living alone is beneficial to individual health contended that relations among household members can create tensions, conflicts, and negative interactions, which damage older adults' health and wellbeing (31). Thus, social conflicts between members of the household are considered an explanation of the health disparities among seniors living with others (5).

2.2.5. Economic wellbeing as a mediator explanation

A substantial amount of literature suggests that living with family members results in an increase in economic wellbeing which promotes one's health status (32). This is because economic wellbeing improves the family's conditions; the sharing of financial and social resources makes the costs more economical. The gathering of wealth also protects against the risk of unexpected out-of-pocket medical and other spending. If living with family members is due to financial constraints but not by self-choice, then the opposite situation could occur.

2.3. The health lifestyle approach

Different from the above theories, the health lifestyle approach can be considered as a theoretical development in research of health disparities (10, 12, 33, 34). The benefit of this perspective is that it has extended the scope of existing analyses on health by merely looking at single health behaviors, such as poor dietary habits, sedentary lifestyle, cigarette smoking, and excessive alcohol consumption that have been commonly used in prior studies (35). Scholars argued that health behaviors tend to cluster in ways that reflect the social and structural contexts of individuals, which in turn affects individual health status (36). This is because behaviors are not isolative but co-occur with one another (34). Health lifestyle theories therefore contended that concentrating on single behaviors or small subsets of risky behaviors provides limited insight into health behavior patterns.

Previous studies have documented an association between living arrangements and older adults' health lifestyles. Chinese older adults who lived with family members were found to have greater odds of reporting good quality of sleep and a longer duration of sleep (20). Older adults who lived alone and who

lived in a large household had a higher risk of inadequate fruit and vegetable intake (37). Older adults who lived alone were found to be more likely to have food insecurity problems and higher possibilities of smoking compared to those living with spouses/partners. It was pointed out that food insecurity, cigarette smoking, and alcohol drinking partially explained the differences in SRH due to living arrangements (38). Meanwhile, scholars also showed a strong link between health lifestyles and individual health outcomes, including mental health, cognitive function, SRH, longevity, and alike (39, 40).

Considering the association between living arrangements and health lifestyles, as well as the link between health lifestyles and health outcomes, that have been documented in the existing literature, this study hypothesized that health lifestyles may serve as a factor mediating the relationship between living arrangements and Chinese oldest-old health outcomes. The selection of health lifestyle as well as health status measures in this study was based on the commonly used measures in previous studies. The analysis answered two main questions: First, how do predominant health lifestyles of the Chinese oldest-old vary among different living arrangement settings? Second, do these main health lifestyles explain part of the health disparities due to the living arrangements of the Chinese oldest-old? The results based on analyzing the Chinese data were supposed to enrich theories explaining the health disparities due to older adults living arrangements in general. Below, the article moved to an introduction of data, measures, and methods used in the study.

3. Data, measures, and methods

3.1. Data

Data came from the 2018 Chinese Longitudinal Healthy Longevity Survey (CLHLS) which was conducted in randomly selected half of the counties/cities in 22 provinces of China. Until now, eight waves (1998, 2000, 2002, 2005, 2008, 2011–2012, 2014, and 2018) of survey data have been collected. The survey was initially launched to meet the needs for scientific research on the oldest-old. Thus, the dataset provided an excellent source for studying seniors in China. It was pointed out that persons who reported an age of 106 years or higher were considered invalid cases (41). Thus, persons aged 106 years and higher were not included in this study due to insufficient information to validate their reported extremely high age. The study eventually obtained 7,943 oldest-old aged 85 to 105 years, with 3,056 male and 4,887 female populations.

3.2. Measures

3.2.1. Living arrangements

The classification of living arrangements fell in line with the classification used in prior literature (13, 42) and it was classified into four mutually exclusive groups. Under each group, the respondent was further classified into sub-groups (please see Table 3 for details). The four mutually exclusive groups were as follows: (1) *Living with a spouse only*: older adults who were living only with their spouse; (2) *Living with adult children/grandchildren*

only: Under these groups, respondents were classified into three sub-groups, which were (a) living with son(s) or grandson(s) only, (b) living with daughter(s) or granddaughter(s) only, and (c) living with both son(s) and daughter(s). Living with daughter-in-law and granddaughter-in-law was considered as living with son and grandson-in-law, respectively; living with son-in-law and grandson-in-law was considered as living with daughter and granddaughter, respectively; (3) *Living with a spouse and child(ren)/grandchild(ren)*: Those who lived with a spouse and child(ren) or grandchild(ren) only. Similarly, three sub-groups were classified under this group, including (a) living with a spouse and son(s) or grandson(s) only, (b) living with a spouse and daughter(s) or granddaughter(s) only, and (c) living with a spouse and both son(s) and daughter(s). Again, living with daughter-in-law and granddaughter-in-law considered as living with son and grandson-in-law, respectively; living with son-in-law and grandson-in-law was considered as living with daughter and granddaughter, respectively; (4) *Living with no spouse, and no children*. Under this group, respondents were classified into three sub-groups, including (a) living alone, (b) living in nursing homes, and (c) living with others (e.g., nephew/niece, siblings, servants, other relatives, etc.).

The preliminary analyses showed that living with son(s)/grandson(s) did not have significant differences with living with daughter(s)/granddaughter(s) when predicting health lifestyle latent class memberships or the respondent's health status. Thus, when running regression analyses, we did not differentiate the respondents living with son(s)/grandson(s) from those living with daughter(s)/granddaughter(s). The living arrangement patterns were classified as six categories in regression analyses, i.e., in addition to the first three categories, the other three sub-categories under the fourth category were considered as the 4th, 5th, and 6th categories (Table 3).

3.2.2. Health lifestyle measures

Health lifestyle measures used in previous analyses generally fell into the following categories:(1) dietary patterns (including eating fruits, vegetables, and breakfast), (2) smoking and alcohol consumption, (3) sleep, (4) obesity and physical activity, (5) seat belt wearing and media use, (6) body mass index (BMI), and (7) regular physical examination (10, 39, 43–48). Due to data constraints, the selection of health lifestyle indicators in this study was based on prior studies and mainly applied four key domains, including dietary behaviors, smoking and alcohol use, sleep, and physical and leisure activities.

The first domain was dietary behaviors. In the CLHLS survey, the respondent was asked about the frequency of eating fresh fruits, fresh vegetables, and drinking tea. Prior research pointed out that tea drinking is related to longevity and reduced risk of mortality and death from cardiovascular diseases (49, 50). Tea consumption was therefore considered to be an important health lifestyle behavior in this study. These three variables were coded as dichotomous ones labeling respondents answering "almost every day" as "1" and "0" if otherwise.

The second domain is related to smoking and alcohol use. Since the variables measuring the respondent's exact amount of

cigarette or alcohol consumption had about 80.0% of responses as missing values, the research therefore applied other alternative measures. The study relied on CLHLS survey questions asking the respondent whether he or she smoked or drank alcohol "in the past" and "at present". The respondent who smoked in the past and at present was coded as "1" and "0" if otherwise. The same rationale and coding strategy were also applied to the alcohol consumption variable.

Sleep was the third domain of health lifestyles given that sleep has been repeatedly treated as an important measure of health lifestyles in previous analyses (11, 34, 39). Sleep was measured by two variables: sleep duration and sleep quality. The sleep duration variable was coded as "1" if the respondent answered having 8 h or more sleep each day and "0" if otherwise. The sleep quality variable was dichotomized with those who reported their sleep quality as "good" and "very good" as "1". Those who reported sleep quality as "so so", "bad", and "very bad" were considered as poor sleep quality and coded as "0".

The fourth domain was physical and leisure activities. The research judged if the respondent was physically active by relying on two survey questions asking whether the respondent exercised regularly in the past and at present. Those who exercised regularly both at present and during the past were coded as "1" and "0" if otherwise. Leisure activities were classified into sedentary and active activities. Epidemiologic studies have utilized measures of moderate-vigorous intensity exercise to define active activity and highly prevalent sedentary behaviors such as television viewing (51). The measures of sedentary and active behaviors were chosen based on such a definition. Sedentary activities were such as reading newspapers/books, playing cards and/or mah-jong, and watching TV and/or listening to the radio. Raising domestic animals and doing gardening work were considered active activities. For those who participated in leisure activities almost every day were coded as "1" and "0" if otherwise.

3.2.3. Health outcome measures

The selection of health outcome measures was based on how health status was operationalized in prior analyses. Although previous studies have applied a striking array of health outcome measures, these measures can largely be classified into four dimensions: (a) mortality, morbidity, and frailty, including chronic illnesses (52–56); (b) perceived health or self-rated health (10, 33, 38, 57); (c) functional health which is indicated as ADL and recurrent falling (58–62); and (d) mental health, such as physiological wellbeing, depression, and cognitive function (63–66). Although the CLHLS questionnaire did not include all of the above health outcome indicators, it did have questions asking about older adults' self-rated health, cognitive function, and subjective wellbeing. These measures are consistent with the above four dimensions of commonly used health outcome measures. In addition, these measures cover the main domains of health measures; therefore, they were used in his study to capture the health status of the respondents.

The respondent's *self-rated health* was coded as an ordinal variable (1 = very bad, 5 = very good). *The cognitive function* of the respondent was measured by using the Chinese version of the

Mini-Mental State Examination (MMSE). The MMSE was adapted from Folstein, Folstein, and McHugh (67) and tested four aspects of cognitive functioning: orientation, calculation, recall, and language. The total possible score on the MMSE is 30, with lower scores indicating poor cognitive ability. Responses of "unable to answer" were coded as incorrect answers.

Regarding subjective wellbeing, the study relied on a number of CLHLS questions that measured the positive and negative feelings of the respondents, respectively. The questions asked about positive feelings included the following: (1) How do you rate your life at present? (2) Do you always look on the bright side of things? (3) Are you feeling energetic? (4) Are you full of hope for future life? (5) Are you happy now as when you were younger?

The questions asked about negative feelings included the following: (1) Are you ashamed, regretted, or guilty about what you have done? (2) Are you angry because you cannot get used to people or things around you? (3) Do you often feel that people around you are not trustworthy? (4) Are you worried about some small things? (5) Is it difficult to concentrate when you are doing things now? (6) Do you feel sad or depressed? (7) Do you feel the older you get the more useless you are? (8) Are you nervous or scared? (9) Do you feel lonely? (10) Do you feel unable to continue your life? (11) Do you feel uneasy, worried, and annoyed? (12) Do you feel that you cannot stop or cannot control worry? (13) Are you worried too much about all kinds of things? (14) Are you very nervous and it is difficult for you to relax? (15) Are you very anxious, so you cannot sit still? (16) Are you easy to get annoyed or easily irritated? (17) Do you feel like something terrible happened?

The responses ranged from 1 to 5 for the questions asking positive feelings with "1" representing always or very good and "5" representing never or very bad. For the first 10 questions measuring negative feelings, the responses ranged from 1 to 5 with "1" indicating the weakest feel and "5" the strongest feel. The coding scale for the rest of the questions measuring negative feelings was somewhat different with responses ranging from "1" to "4". Similarly, "1" represented never and "4" represented almost every day. Thus the maximum positive and negative feeling scores are 25 and 78, respectively. Since CLHLS data were not collected to examine the psychological wellbeing of older adults, the above question may not be a perfect indicator of one's subjective wellbeing. However, Chen and Shot (13, p. 1388) indicated that "they represent important dimensions of subjective wellbeing, such as life satisfaction, happiness, and loneness." Thus, measures associated with the above questions were considered as legitimate indicators of the oldest-old psychological wellbeing.

The response codes were summed, creating a range of 5 to 25 for the positive feeling score and 17–78 for the negative. The internal consistency coefficients for the two summed scores were alpha = 0.70 and 0.87, respectively. These values indicated that the two summed scores were valid and acceptable. The logic behind the strategy was that each group of variables measured the same concept. This strategy reduced the number of variables in the analysis and improved the efficiency of the regression models. After summing each set of variables to a single variable, Cronbach's alpha was applied to assess the reliability of a given set of variables (68).

3.2.4. Control variables

The study also controlled for the respondent's demographic and socioeconomic characteristics, including age, gender, rural/urban residence, education, and per capita household income. The early childhood (or parental) socioeconomic status (SES) was also controlled because socioeconomic condition in early childhood was found to have a cumulative effect on one's later life health status and mortality (69, 70). Such measures were whether the respondent frequently went to bed hungry as a child and the education of the respondent's father. Table 1 shows descriptive statistics for all variables used in the analysis.

3.3. Methods

3.3.1. Latent class analysis

Latent class analysis (LCA) was used to conduct the analyses in Stata 16.0 software to predict membership in latent or unobserved groups that share similar health lifestyle patterns among the Chinese oldest-old. LCA differs from factor analysis in that it uses dichotomous, not continuous, indicators and assumes that there are underlying discrete groups or classes of respondents. Membership in sub-groups is based on the similarities in individual responses to questions that are related to a set of observed behaviors. Latent classes of health lifestyles were created from the health lifestyle measures described in the previous section. Each case was assigned a probability of membership in each class. An exploratory approach was applied since the exact number of health behavior typologies is unknown. It started with the most parsimonious 1-class model and fitted successive models with increasing numbers of classes. Each latent class solution was replicated 20 times beginning at random starting values. This method included a close examination of item loadings and model fit indices for estimating latent classes (71).

The final number of classes was determined by the conceptual meaning, and commonly used fit measures such as the Akaike information criterion (AIC), the Bayesian Information Criterion (BIC), and the value of entropy. The AIC and BIC values for different class categories are presented in Table 2. The Stata software showed that convergence was not achieved when constructing four classes. Therefore, the study only presented the AIC, BIC, and entropy values for the first three classes. Since smaller values of AIC and BIC are better, the three-class model was considered the best fit. The entropy for the three-class model (0.703) is beyond the criteria for a good class separation cutoff point of 0.60 (72). The three-class solution also provided the most conceptually coherent description of health lifestyles. It was therefore chosen as the most appropriate solution. Table 4 shows item response probabilities and shares for the sample for each class.

3.3.2. Other analyses

Descriptive analysis was used to report means and percentage distributions of all variables. To investigate whether health lifestyles served as a mediator in the association between living arrangements and Chinese oldest-old health, the study constructed several regression models: (1) ordinary least square (OLS) regression models detecting the association between

TABLE 1 Summary statistics for all variables: Chinese oldest-old aged 85–105 (N = 7,943).

Variables	Mean (or %)	SD	N
Health lifestyle variables			
1) R eats fresh fruit almost everyday	21.1		7,884
2) R eats fresh vegetables almost everyday	41.6		7,891
3) R drinks tea almost everyday	12.3		7,713
4) R smoked before and still smokes	10.2		7,943
5) R drank before and still drinks	9.7		7,943
6) R had good quality of sleep	52.9		6,808
7) If R normally sleeps at least 8 hours	53.5		7,290
8) R exercised regularly during the past and still regularly exercises at present	15.9		7,943
9) R participates active leisure activities frequently	27.1		7,943
10) R participates sedentary leisure activities frequently	40.4		7,943
Health status variables			
1) R's self-rated health (mean)	3.4	0.9	6,737
2) R's cognitive function score (mean)	26.8	3.8	2,079
3) R's positive feeling score	12.7	3.4	5,510
4) R's negative feeling score	29.0	7.5	5,050
Control variables			
R's characteristics			
Age (mean)	94.7	5.9	7,943
Gender (male = 1)			7,943
Male	38.5		
Female	61.5		
Rural/urban residence (urban = 1)			7,943
Urban	55.9		
Rural	44.1		
R's reported years of schooling (mean)	2.0	3.6	6,855
R's household per capita income	14,454.8	14,540.1	5,772
R's parental characteristics			
Whether R often went to bed hungry in childhood			6,288
Yes	75.3		
No	24.7		
R's father's years of schooling (mean)	0.7	2.1	6,301

Some sub-categories may not add up to 100% due to rounding. R, respondent.
Source: Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2018 data.

living arrangements (X) and oldest-old health status (Y); (2) multinomial logit models showing how living arrangements (X) related to health lifestyle class membership, that is, oldest-old health lifestyles (M); and (3) adding health lifestyle covariates (M) into OLS regression models constructed in step (1) to evaluate whether health lifestyles served as a mediator. We followed Barton and Kenny's (73) rationale that has been widely used in social sciences to detect the existence of mediating effects. Specifically, if c, a, and b in Figure 1 were all significant, then a mediating effect existed. If adding M

covariates made c' non-significant, then M had a perfect mediating effect (73, 74).

When using health lifestyles to predict the oldest-old health outcomes, multinomial logistic regression models were constructed. The multinomial logit regression equation is as follows:

$$Logit\ k = logit \frac{\Pi_k}{\Pi_n} = \beta_k' X, K = 1, 2, \ldots \ldots, n-1$$

where

$$\prod_k = \frac{\exp(\beta_k' X)}{1 + \sum_{k=1}^{n-1} \exp(\beta_k' X)}$$

$$\prod_n = \frac{1}{1 + \sum_{k=1}^{n-1} \exp(\beta_k' X)}$$

In multinomial logit models, the dependent variable had three categories or classes. Class 3 was treated as the base category for comparison. Table 5 shows the multinomial logistic regression results when comparing class 3 with the other two classes, respectively, controlling for the respondent's demographic and socioeconomic characteristics.

4. Results

4.1. Descriptive statistics

Table 1 shows descriptive results for all variables. Of the 7,943 respondents aged 85 to 105 years, 61.5% of them were females. The

TABLE 2 Summary of latent class model identification and statistics (*N* = 6,553).

No. of classes	AIC	BIC	Entropy	Likelihood ratio chi-squared
1	71,193.2	71,261.1	-	5,086.2
2	69,455.3	69,597.9	0.613	3,326.3
3	**68,432.3**	**68,649.5**	**0.703**	**2,281.3**

AIC, Akaike's information criterion; BIC, Bayesian information criterion.
Bolded row represents the identified model.

FIGURE 1
Illustration of a direct effect **(A)** and a mediation design **(B)**.

percentage share of urban respondents was higher than that of rural ones (55.9% and 44.1%, respectively). The mean age of the sample was 94.7 with a standard deviation of 5.9. The SES of the studied sample appeared to be low. On average, the years of schooling among the studied sample was 2.0 with a standard deviation of 3.6. The mean household per capita income for the year before the survey was 14,454.8 RMB (which is equivalent to 2,065.0 USD with 1 USD = 7 RMB), with a standard deviation of 14,540.1 RMB. About 75.3% of the studied sample reported being hungry when going to bed in their childhood. The paternal socioeconomic status was even lower with an average year of paternal schooling of 0.7 with a standard deviation of 2.1.

As to health outcome variables, the SRH was fairly good with a mean score of 3.4 (between fair and good). The mean cognitive function score was 26.8, indicating good cognitive function considering the maximum cognitive function score was 30. The positive feeling score ranged from 5 to 25 and the negative feeling score ranged from 17 to 71. The mean positive and negative feeling scores were 12.2 and 29.0, respectively, suggesting that the sampled Chinese oldest-old had fairly positive subjective wellbeing.

For health lifestyle measures, the results showed that 21.1% and 41.6% of the respondents reported that they ate fresh fruits and vegetables almost every day and 12.3% of the oldest-old drank tea almost every day. About 10.2% of the studied sample were smokers and still smoked when the survey was conducted. In total, 9.7% of the respondents were drinkers and were still drinking in the survey year. About half of the respondents reported good quality sleep, and about 53.5% of them had 8 or more h of sleep each day. The results showed that 15.9% of the oldest-old reported that they did physical exercise before the age of 60 years and were still exercising when surveyed. About 27.1% and 40.4% of the respondents answered that almost every day they participated in at least one physical and sedentary type of leisure activity, respectively.

Table 3 shows the living arrangement patterns of the sampled oldest-old. The oldest-old who co-resided only with their son(s) or grandson(s) were the majority of the sample (47.2%). Such a percentage was higher among rural than among urban respondents (53.1% vs. 42.5%). Those who lived alone were the second largest group, which accounted for 16.3% of the overall sample (18.4% for urban vs. 14.6% for rural). It was followed by the group who lived only with daughter(s) or granddaughter(s) and the group who lived only with a spouse, which were 10.8% and 10.1% of the overall sample, respectively. The percentage of those who lived only with daughter(s) or granddaughter(s) was higher among urban oldest-old (12.5%) than among rural ones (8.7%). There was a slightly higher percentage of respondents who co-resided with a spouse in urban than in rural settings (10.6% vs. 9.5%). The other types of living arrangement patterns were not popular. About 7.7% of urban oldest-old reported living in nursing homes and the corresponding percentage for their rural counterparts was only 1.7%.

4.2. The health lifestyles among Chinese oldest-old

Since the 3-class model was chosen as the best-fitted latent class model, the study estimated item probabilities for three identified

latent classes. Table 4 presents the three predominant healthy lifestyles (latent classes) among the Chinese oldest-old and their share of the sample. Class 1 can be described as having a less healthy diet, not smoking, not drinking, poor sleep, and low engagement in physical exercise and leisure activities, which contained 45.0% of the sampled Chinese oldest-old in this group and may be labeled as having "negative behaviors". This group showed that there were very low probabilities of respondents eating fruits or drinking tea every day. They were more likely to be non-smokers or non-drinkers both currently and during the past, and they had poor sleep and reported low engagement in leisure activities and physical exercise. This class was the majority among the three classes.

About 25.9% of the respondents fell into Class 2, which can be described as having a less healthy diet, not smoking, not drinking, good sleep, and low engagement in physical exercise and leisure activities. This group may be labeled as having "adequate sleep". For this group, the probabilities of respondents drinking tea and eating fresh fruits/vegetables were slightly higher as compared to the first group. They were not smokers or drinkers previously or at the survey time and had low probabilities of exercising and participating in leisure activities. A dominant feature of this class was that this class had the best sleep among all three groups.

Class 3 can be classified as consistent engagement of healthy behaviors, which accounted for 29.1% of the studied sample and may be labeled as having "healthy behaviors". This class showed the highest probabilities of having healthy dietary patterns (eating fresh vegetables and fruits almost every day; drinking tea almost every day), not being smokers or drinkers, having enough sleep (≥ 8 h per day), and reporting good quality sleep, participating in active and sedentary leisure activities and doing physical exercises. Based on the above results, class 3 was labeled as consistently positive by showing overall healthier lifestyles relative to nearly all measures and domains.

The other two classes are composed of particular domains of unhealthy behaviors.

4.3. Living arrangements and Chinese oldest-old health lifestyles

The study then constructed multinomial logistic regression models to investigate the associations between oldest-old living arrangement patterns and their health lifestyles, i.e., how living arrangements predicted health lifestyles. Class 3, the consistently positive group, was treated as the baseline group and the other two classes were compared with class 3. Results presented in Table 5 show that respondents who lived only with a spouse and those who lived with a spouse and children/grandchildren were more likely to be in the other two classes than in class 3. Those who lived alone were more likely to be in class 1 (less healthy diet, not smoking, not drinking, poor sleep, and low engagement in physical exercise and leisure activities) than in class 3. These findings indicated that the Chinese oldest-old who lived only with children/grandchildren were more likely to have healthier lifestyles than those who co-resided only with a spouse, those living with a spouse and children/grandchildren together, and those who lived alone.

As to control variables, the results indicated that with age increasing, the Chinese oldest-old were less likely to be in the other two classes than in class 3, suggesting they tended to have healthier lifestyles while aging. As compared to women, men were less likely to be in class 1 but more likely to be in class 2 (less healthy diet, not smoking, not drinking, good sleep, and lowest engagement in physical exercise and leisure activities) than in class 3. Urban seniors were less likely to be in class 1 but more likely to be in class 2 than in class 3 as compared to their rural

TABLE 3 Residential arrangements of oldest-old in China (%).

Variable	Urban (N = 4,373)	Rural (N = 3,444)	Total (N = 7,817)
Living with a spouse only	10.6	9.5	10.1
Living with adult children or grandchildren, no spouse			
Son or grandson only	42.5	53.1	47.2
Daughter or granddaughter only	12.5	8.7	10.8
Both son/grandson and daughter/granddaughter	3.2	3.1	3.2
Living with spouse and adult children/grandchildren			
Son/grandson only	4.1	4.1	4.1
Daughter/granddaughter only	1.1	0.5	0.8
Both son/grandson and daughter/granddaughter	0.4	0.1	0.3
Living with no spouse, no adult children			
Nursing home	7.7	1.7	5.0
With others	3.3	0.8	2.2
Living Alone	14.6	18.4	16.3

Some sub-categories may not add up to 100% due to rounding.
Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2018 data.

TABLE 4   Item response probabilities for health lifestyle indicators used in latent class analysis: Chinese oldest-old aged 85−105.

Variables	Class 1 (Less healthy diet, not smoking, not drinking, poor sleep, low physical exercise and leisure activities; 45.0%)	Class 2 (Less healthy diet, not smoking, not drinking, good sleep, low physical exercise and leisure activities; 25.9%)	Class 3 (Consistent engagement in healthy behaviors; 29.1%)
Health lifestyle indicators			
1. Eating fresh fruit almost everyday			
Yes	0.092	0.189	0.425
No	0.908	0.811	0.575
2. Eating fresh vegetables almost everyday			
Yes	0.462	0.563	0.839
No	0.538	0.437	0.161
3. Drinking tea almost everyday			
Yes	0.062	0.093	0.278
No	0.938	0.907	0.722
4. Smoking			
Yes	0.069	0.100	0.188
No	0.931	0.900	0.812
5. Drinking			
Yes	0.065	0.094	0.181
No	0.0.935	0.906	0.819
6. Good quality of sleep			
Good	0.227	0.937	0.636
Poor	0.773	0.063	0.364
7. Normally sleeps at least 8 h			
Yes	0.234	0.999	0.560
No	0.766	0.001	0.440
8. Exercising during the past and at present			
Yes	0.079	0.100	0.406
No	0.921	0.900	0.594
9. Participating in physical leisure activities almost daily			
Yes	0.270	0.175	0.475
No	0.730	0.825	0.525
10. Participating in sedentary leisure activities almost daily			
Yes	0.281	0.286	0.856
No	0.719	0.714	0.144

All variables are coded 1 = yes, 0 = no.
Sources: Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2018 data.

counterparts. Higher education and family income pushed the oldest-old to be more likely in class 2. Respondents who frequently went to bed hungry in childhood were less likely to be in class 2 than in class 3. These results demonstrated that demographic features as well as individual and parental SES significantly linked to the Chinese oldest-old health lifestyle class membership, that is, as compared to class 3, socioeconomically disadvantaged groups

were more likely to be in class 1 but the oldest-old with higher SES tended to have a greater likelihood of being in class 2. This meant that higher SES does not always lead to healthier lifestyles. The sampled Chinese oldest-old with higher SES indeed tended to fall into class 2 which has an unhealthy diet, sedentary lifestyle, and good sleep quality. These findings will be discussed in the discussion section.

TABLE 5 Multinomial logistic regression on R's health lifestyle latent classes: Chinese oldest-old aged 85–105.

Variables	Class 1 vs. class 3		Class 2 vs. class 3	
	RRR	S.E.	RRR	S.E.
R's living arrangement patterns				
(Ref.= living with children or grandchildren only, no spouse)				
Living with a spouse only	1.58***	0.14	1.56**	0.14
Living with spouse and children/grandchildren	1.41***	0.18	1.49**	0.17
Living alone	1.89**	0.21	1.09	0.25
Living in nursing homes	1.20	0.51	0.35	0.70
Living with others	1.38	0.25	1.50	0.25
Control variables				
Age	0.95***	0.01	0.90***	0.01
Sex (Ref. = female)	0.66***	0.09	1.34**	0.10
Residence (Ref. = rural)	0.65*	0.08	1.58***	0.09
R's years of schooling	0.99	0.02	1.06***	0.01
R's natural logged per capita family income	0.92**	0.03	1.14***	0.03
If R often when to bed hungry in childhood	0.89	0.10	0.79*	0.10
R's father's years of schooling	0.99	0.02	1.0	0.02
Constant	5.30***	0.73	7.20***	0.81
N	4,223		4,223	
LR Chi- squared	654.65		654.65	
Log likelihood	−4,292.0	2	−4,292.02	

R refers to the respondent; *represents p < 0.05; **p < 0.01; ***p < 0.001. RRR, relative risk ratio.
Sources: Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2018 data.

4.4. The influence of living arrangements and health lifestyles on Chinese oldest-old health

This section of the analysis started to follow Baron and Kenny's (73) strategy by performing regression analyses to detect if health lifestyles served as a mediator in the association between living arrangements and Chinese oldest-old health. The study first performed OLS regression in models 1, 3, 5, and 7 by using living arrangements to predict the respondent's health status which was measured by SRH, cognitive function, and positive and negative feelings, respectively. Models 2, 4, 6, and 8 further added health lifestyle covariates in OLS regression models to discover if health lifestyles served as a mediator linking living arrangements and the oldest-old health (see Tables 6A, B).

Models 1 and 2 in Table 6A showed that the average SRH score for the oldest-old who lived only with a spouse was 0.22 lower than those who lived only with children/grandchildren. The significant regression coefficient for health lifestyle covariates was significant as well, suggesting that as compared to class 3, the oldest-old in class 1 tended to report worse SRH but respondents in class 2 tended to report better SRH scores. When adding health lifestyle classes in model 2, the regression coefficient became smaller, indicating health lifestyles served as a mediator which partially explained the association between living arrangements and SRH.

Models 3 and 4 presented regression results when predicting the cognitive function status of the Chinese oldest-old. Although cognitive function scores for the oldest-old in class 2 were 0.81 points higher than that of the reference group, class 3, living arrangements did not show significant effects on respondents' cognitive function. Thus, no mediating effect existed.

The results in models 5 and 6 in Table 6B showed that the oldest-old who only lived with a spouse and those who lived with a spouse and children together tended to report higher positive wellbeing scores than those who lived only with children/grandchildren. The coefficients for health lifestyles covariates were significant. When adding health lifestyle classes in model 6, the significant health disparities between the reference group and the group who lived with a spouse and children/grandchildren disappeared. It indicated that the mediating effect of health lifestyles existed, which perfectly explained the health disparities caused by living arrangement differences, but the oldest-old who lived only with a spouse still showed higher positive wellbeing scores than the reference group, even after health lifestyles and other factors were controlled.

Models 7 and 8 further showed regression results when predicting the oldest-old negative wellbeing scores. Those who lived alone showed a significantly higher negative wellbeing score than the reference group in model 7. Adding health lifestyle memberships in model 8 made such a significant effect disappear. It

TABLE 6A OLS regression of self-rated health and cognitive function on living arrangements, health lifestyle latent classes and other control variables: Chinese oldest-old aged 85−105.

Variables	Self-rated health				Cognitive function			
	Model 1		Model 2		Model 3		Model 4	
	b	*p* value	b	*p* value	b	*p* value	b	*p* value
R's living arrangement patterns (Ref.= living with children or grandchildren, no spouse)								
Living with a spouse only	−0.22	0.000	−0.20	0.000	0.46	0.138	0.41	0.189
Living with spouse and children/grandchildren	−0.00	0.961	−0.00	0.986	0.53	0.193	0.47	0.252
Living alone	−0.01	0.868	0.04	0.574	0.22	0.711	0.22	0.700
Living in nursing homes	0.11	0.585	0.19	0.339	−0.27	0.875	−0.34	0.841
Living with others	0.06	0.540	0.06	0.494	−0.40	0.540	−0.43	0.504
Health lifestyle latent class (Ref.= Class 3: Consistent engagement in healthy behaviors)								
Class 1 (less healthy diet, not smoking, not drinking, poor sleep, low physical exercise and leisure activities)	-	-	−0.29	0.000	-	-	0.30	0.354
Class 2 (less healthy diet, not smoking, not drinking, good sleep, lowest physical exercise and leisure activities)	-	-	0.20	0.000	-	-	0.81	0.005
Control Variables								
Age	−0.00	0.522	0.00	0.928	−0.13	0.000	−0.12	0.000
Sex (Ref. = female)	0.03	0.366	−0.03	0.463	0.71	0.007	0.70	0.008
Residence (Ref. = rural)	0.01	0.823	−0.01	0.677	0.09	0.712	0.01	0.988
R's years of schooling	−0.01	0.723	−0.01	0.117	0.09	0.009	0.07	0.020
R's natural logged per capita family income	0.07	0.000	0.06	0.000	0.22	0.020	0.19	0.037
If R often when to bed hungry in childhood	−0.07	0.047	−0.07	0.027	−0.34	0.167	−0.34	0.171
R's father's years of schooling	−0.02	0.044	−0.02	0.000	0.02	0.703	0.02	0.655
Constant	3.04	0.000	3.05	0.000	36.24	0.000	35.34	0.000
N	3,680				1,165			

* <0.05, ** <0.01, *** <0.001. R, respondent. b, regression coefficient; S.E., standard error.
Sources: Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2018 data.

indicated a medicating effect of health lifestyles, i.e., health lifestyles perfectly explained the significant differences in negative wellbeing scores between the reference group and the group who lived alone. The health lifestyle covariates showed significant effects. Class 1 tended to have a negative wellbeing score of 2.5 points higher than the reference group; whereas class 2 tended to report a score of 0.88 lower than class 3.

Control variables showed significant correlations with the respondent's health. An increasing age is related to a worse cognitive function and a lower negative wellbeing score. Male participants tended to have better cognitive function and better subjective wellbeing. The urban oldest-old seemed to have a higher negative wellbeing score than their rural counterparts. Higher education was linked to better cognitive function and a higher positive wellbeing score. High income showed significant positive effects on SRH, better cognitive function, and subjective wellbeing. Going to bed hungry in childhood had significantly negative effects

on the oldest-old SRH and subjective wellbeing. Such findings supported the cumulative disadvantage theories that childhood disadvantage explained part of the health disparities in older ages. In sum, the findings of this research proved that some of the health differentials linked to the oldest-old living arrangement patterns can be explained by their health lifestyles in various household contexts. In other words, health lifestyles served as a factor mediating the association between living arrangements and Chinese oldest-old health status, after controlling for demographic and socioeconomic covariates.

5. Conclusion and discussion

Through analyzing samples aged 85 to 105 years from data of the CLHLS 2018 wave, the research tried to fill the voids of prior literature by elucidating the mediating effect of health

TABLE 6B OLS regression of subjective wellbeing on living arrangements, health lifestyle latent classes and other control variables: Chinese oldest-old aged 85−105.

Variables	Positive wellbeing				Negative wellbeing			
	Model 5		Model 6		Model 7		Model 8	
	b	p value	b	p value	b	p value	b	p value
R's living arrangement patterns (Ref.= Living with children or grandchildren, no spouse)								
Living with a spouse only	0.45	0.002	0.57	0.003	0.10	0.818	−0.02	0.961
Living with spouse and children/grandchildren	0.40	0.020	−0.08	0.744	−0.38	0.518	−0.42	0.466
Living alone	0.09	0.727	0.08	0.808	1.72	0.019	1.30	0.072
Living in nursing homes	−1.06	0.129	0.08	0.925	2.40	0.189	1.79	0.318
Living with others	0.41	0.105	−0.22	0.555	1.38	0.101	1.20	0.146
Health lifestyle latent class (Ref.= Class 3: Consistent engagement in healthy behaviors)								
Class 1 (less healthy diet, not smoking, not drinking, poor sleep, low physical exercise and leisure activities)	-	-	−0.29	0.000	-	-	2.52	0.000
Class 2 (less healthy diet, not smoking, not drinking, good sleep, lowest physical exercise and leisure activities)	-	-	0.20	0.000	-	-	−0.88	0.013
Control variables								
Age	−0.00	0.522	0.00	0.928	−0.05	0.037	−0.06	0.020
Sex (Ref. = female)	0.03	0.366	−0.03	0.463	−1.16	0.000	−0.73	0.024
Residence (Ref. = rural)	0.01	0.823	−0.01	0.677	0.51	0.085	0.64	0.027
R's years of schooling	−0.01	0.723	−0.01	0.117	−0.07	0.127	−0.03	0.485
R's natural logged per capita family income	0.07	0.000	0.06	0.000	−0.52	0.000	−0.42	0.000
If R often when to bed hungry in childhood	−0.07	0.047	−0.07	0.027	0.71	0.034	0.70	0.032
R's father's years of schooling	−0.02	0.044	−0.02	0.000	0.03	0.662	0.03	0.605
Constant	3.04	0.000	3.05	0.000	38.24	0.000	37.03	0.000
N	3,680				2,782			

b, regression coefficient; S.E., standard error.
Sources: Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2018 data.

lifestyles. Three latent classes representing three predominant health lifestyles among Chinese oldest-old emerged, which were labeled as groups having "negative behavior", "adequate sleep", and "constant positive behaviors", respectively. Individuals in class 1 accounted for nearly half of the studied sample, which represented the most popular health lifestyles of the Chinese oldest-old. Only about one-third of the respondents demonstrated healthy lifestyles.

Nearly half of the oldest-old were found to live only with son(s)/grandson(s), which was the most popular living arrangement pattern, followed by living alone, living only with daughter(s)/granddaughter(s), and living only with a spouse. The rest types of living arrangements were uncommon. The results were consistent with previous findings that co-residing with one or more adult children is still a fundamental household structure in China (15). Living arrangement patterns were also found to be significantly correlated with the oldest-old health lifestyles. As compared to those who lived only with adult children/grandchildren, those who lived only with a spouse, and those who lived with a spouse and child/grandchildren together were more likely to be in class 1 (having poor sleep, unhealthy diet, and a sedentary lifestyle) and class 2 (having good sleep, unhealthy diet, and a sedentary lifestyle) than in class 3. Those who lived alone were also more likely to be in class 1 than in class 3. These results suggested that besides having an unhealthy diet and a sedentary lifestyle, the oldest-old who lived alone were especially more likely to experience poor sleep. Such results fell in line with findings of prior literature that Asian older adults who lived with family members had greater odds of reporting good quality of sleep and a longer duration of sleep (20, 75). The oldest-old living only with son(s)/grandson(s) were more likely to be in class 3 and have healthier lifestyles than those in other types of household contexts. Living with a spouse did not seem to aid older adults in forming healthier lifestyles.

When predicting health outcomes, in addition to cognitive function, living arrangements were found to have significant correlations with the respondent's health. Specifically, as compared to the oldest-old who co-resided only with their children or grandchildren, those living only with a spouse reported worse SRH. Individuals who lived only with a spouse and those who lived with a spouse and children/grandchildren together reported higher positive wellbeing scores than those who lived only with son(s)/grandson(s). Living alone significantly increased the respondent's negative wellbeing score. It seemed that co-residing with a spouse is a critical factor that promoted the oldest-old positive wellbeing, whereas the absence of other family members significantly deteriorated elders' subjective wellbeing.

Health lifestyles were found to serve as a mediator that partially explained the respondent's SRH disparities. That is, the oldest-old who lived only with a spouse had a worse SRH score because they had unhealthy lifestyles than those who co-resided only with son(s)/grandson(s). Health lifestyles thus partially explained SRH differentials. Health lifestyles did not show a mediating effect when predicting cognitive function. Regarding positive wellbeing, when adding health lifestyles in the model, although the oldest-old living only with a spouse still showed significantly higher positive feeling scores than those who lived only with son(s)/grandson(s), the health advantage of those who lived with a spouse and children/grandchildren disappeared. The findings implied that no matter whether the respondent lived with a spouse or not, co-residing with adult children/grandchildren helps older adults to shape healthy lifestyles, which perfectly explains the differentials in positive feelings caused by living arrangements.

The mediating effect of healthy lifestyles may be explained as follows: First, adult children/grandchildren have more updated health-related knowledge than the oldest-old and their spouse who is most likely to be an oldest-old individual as well. Adult children/grandchildren who lived with the oldest-old are also more capable of facilitating their elder parents/grandparents to practice healthy behaviors than the respondent's spouse. Second, it is possible that those living alone are also likely to have sedentary, isolated, and unhealthy lifestyles, which may have caused their worse health condition and stronger negative feelings. Thus, health lifestyles serve as a mediator in this study.

The literature review section reviewed five theories to elucidate how living arrangements may possibly explain the health disparities among older adults with various living arrangement patterns. The mediating effects discovered in this research inform the reader that health lifestyles may serve as a theoretical explanation of the above association. It can be named *healthy lifestyles as a mediator explanation* of the health disparities among the oldest-old in different household contexts. This finding not only enriched the existing theories on older adults' living arrangements and health but also had important practical implications. Caregivers, clinicians, and professionals may consider assisting older adults to form healthier lifestyles to improve their health and longevity. The research results echoed the arguments of researchers that multiple health behavior change interventions outperformed single-behavior interventions in health promotion (76, 77). Results based on analyzing the China data also provided valuable

implications to address disease prevention and health promotion-related issues among older adults in other countries.

It was found that the oldest-old living only with son(s)/grandson(s) generally had a greater chance to be in class 3 ("having constant positive behaviors") than those living in other types of household structures, suggesting that the oldest-old living with son(s)/grandson(s) tended to have healthier lifestyles. The *Filial piety theory* contends that living with married sons benefits older adults' health, especially psychological wellbeing (27, 28). The findings of this research, however, challenged this theory by showing being in class 3 did not lead to the best health outcomes. Instead, the oldest-old in class 2 reported better SRH, cognitive function, and subjective wellbeing than those in class 3. Higher SES among individuals in class 2 likely contributed to their better health outcomes. Regression results showed that the oldest-old with higher income and education were more likely to be in class 2 ("adequate sleep group") than in class 3. Their high SES somehow offsets the negative effects of unhealthy lifestyles on health. This group therefore demonstrated the best health outcomes among all three classes. Such findings can be explained by China's current transitional stage in which consuming high-fat and energy-condensed food and having a more sedentary lifestyle are considered a privilege of people with higher SES (78). Thus, the oldest-old in class 2 had less healthy lifestyles but better health outcomes. Positive links between higher SES, healthier lifestyles, and better health outcomes are expected to occur among individuals in China after the country completes its social and economic transitions in years to come.

The study had several limitations. First, the research was not able to exhaust all possible health lifestyle measures due to limited CLHLS survey questions relating to health lifestyles. Some important health lifestyle indicators, such as vaccination injections and doctoral visits, have not been included in this research. Second, measures of one's health status were also relatively crude. Future research may consider applying additional health outcomes as well as health lifestyle measures to improve current analysis. In addition, the quality of living arrangements and duration of stay in certain household contexts were not controlled in the analysis due to data constraints. Since the quality of care provided in the household may differ among the oldest-old with the same living arrangement type and the duration of stay in certain living arrangement patterns may link to the oldest-old health, future research should consider these dimensions. Finally, although the study showed a mediating effect of health lifestyles, there may be a causality issue between health lifestyles and health outcomes. It could be the case that healthier individuals are more likely to have healthier lifestyles, which in turn benefits one's health. Future research should further address the causality issue to yield a more comprehensive understanding of living arrangements, health lifestyles, and the oldest-old health outcomes.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://opendata.pku.edu.cn/file.xhtml?fileId= 10357.

Author contributions

LiZ and JW were major contributors. LiZ designed the research, conducted literature review, analyzed data, and wrote the original draft. JW conducted literature review and formal analysis and revised the manuscript. LaZ and SW conducted literature review, analyzed and interpreted data, and revised the manuscript. All authors read and approved the final manuscript.

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Conflict of interest

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

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Understanding the influencing factors and mechanism of social compensation for Chinese older adults using social media in the context of smart home: a qualitative analysis

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As a new generation of necessary terminals for future homes, smart homes have become one of the essential mediums for smart aging at home. This paper aims to explore how older adults who age at home can overcome the digital divide of the new medium and achieve social participation in the home context to realize active aging. Based on the theory of social compensation, we select the smart-home smart screen, a representative new medium product in China, and carry out open coding, spindle coding, selective coding, and theoretical construction of the original interview data through the grounded theory research method. The results show that the main factors affecting the social compensation of older adults to smart home social media include user interface quality, interaction quality, content quality, and service quality, and these four factors are used as external variables to compensate older adults socially, thereby stimulating the emotional experience and perception changes at the cognitive level of older adults and then affecting the adoption and acceptance of smart home social media by older adults. This study refines the factors influencing the older adults' use of smart home social media from the perspective of social compensation. It explains the mechanism of acceptable behavior of older adults, bridging the gap in previous literature on the influencing factors and behavioral mechanisms of older adults of smart home social media. This paper provides a theoretical basis and guidance for the subsequent academic research and software development practice of social media under new technological devices to further help older adults in China achieve active and healthy aging.

KEYWORDS

compensation theory, social media, social compensation, smart screen technology for smart homes, Chinese older adults, grounded theory, qualitative analysis, users' acceptance behavior

1. Introduction

China is in the midst of an aging and digitalized society. On the one hand, China's aging problem is severe, and the seventh national census of China, released in May 2021, shows that 18.7% of the total population, or 264 million people, are aged 60 and over, up 5.44% from the sixth census (1). Among them, the number of older adults living alone and empty nesters increased to 118 million, and it is expected that the number of empty nesters will exceed 200 million by 2030 (2). At the same time, the lower-aged older adult population aged 60–69 accounts for 55.83% of the total number of older adults, or about 10.44% of the total population (3). This is a significant increase in the number of older adults in China. The current situation in China is that the aging population continues to rise, with a large proportion of older adults living alone, empty nesters, and a high proportion of young older adults. To solve the problem of aging the first step is to solve the problem of old-age care. Since the pension model adopted in China is a "90-7-3" home-based care pattern (4), 90% of older adults aged 60 or above live at home. The remaining 10% choose daycare home-based services, and only a few attend institutions. Thus, more than 90% of older adults in China live at home. The main issue confronting a large number of older adults living alone and empty nesters is how to meet their social participation needs. Social participation is a fundamental factor that affects whether older adults can live independently and actively (5). Older people themselves are also willing to spend time maintaining contact with family and close friends (6). However, due to the decline in physical functions, mobility difficulties, retirement from the workforce, shrinking social circles, the impact of the post-epidemic era, as well as the need to cope with the sadness caused by widowhood and the loss of loved ones and friends, the above personal and social factors can lead to a lack of social interaction between the older adults and the rest of society, resulting in social isolation. They may feel lonely and emotionally unsupported, which can be psychologically damaging. Loneliness is associated with and synergistic with depression, reducing older adults' well-being (7). Loneliness also increases the risk of death in older adults (8). Studies have shown that social interaction and participation in social activities can not only help alleviate social isolation and loneliness in older adults (9), but also help reduce the risk of Alzheimer's disease (10). Therefore, how encouraging the social participation of older adults living alone at home has become an important practical issue.

On the other hand, as technology has advanced, China has entered an era of digitalization and intelligence, which has sped up the process of intelligent innovation in the household unit system. The smart home smart screen series is a kind of smart home product that began to rise in China in recent years (Figure 1). Smart homes are easier for older adults to use as AI personal assistants than smartphones. Voice interaction lets older adults control smart homes for social behavior even if they do not know Chinese characters. At the same time, technological advances have made smart aging an inevitable trend. In 2022, China's State Council put forward the requirement of promoting technical and intelligent upgrading of older adults' products and requested further promotion of competent services to adapt to the needs of older adults and build an intelligent society that takes the needs of the older adults into account (11). As a new means of older adult care, smart older adult care has become a helpful initiative to cope with China's aging society (12). Smart home products are becoming increasingly popular, and their relative ease of access, low cost, and application in home scenarios make them one of the most critical products for smart aging. Intelligence and digitalization play an essential role in helping older adults improve their lives (13, 14). The use of smart homes has the potential to enhance the social participation of older adults and enable them to play an active role in smart wellness at home. However, older adults' physical and psychological uniqueness makes them reluctant to embrace new technologies and products. Studies show that the most common reasons for older adults to withdraw from using the Internet are psychological and health barriers (15), making it difficult for them to enjoy the convenience of new technologies and products. China's State Council points out the huge digital divide facing China's older adults (16). Since smart homes are relatively new products, the digital divide makes the adoption and acceptance of using smart homes for online social behavior by older adults a topic worth exploring and studying. Providing a better design of smart home social software for older adults to make them have a better user experience can give inspiration to effectively solve the digital divide problem of older adults (17, 18) and thus enable smart aging for older adults and practice active aging. However, few studies have investigated the factors and mechanisms influencing the adoption of smart home socialization among older adults.

Therefore, predicting the acceptance of older adults to use smart home social media becomes very important, and accurately capturing the factors that influence the use of smart home social media by older
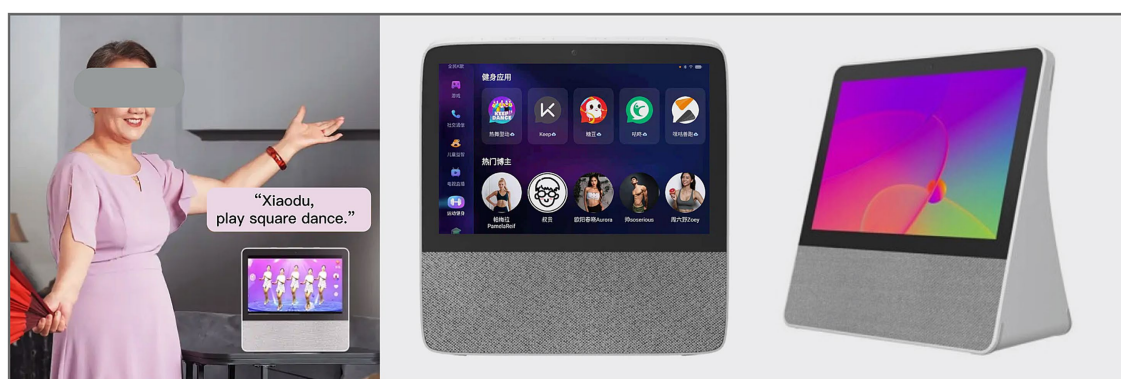

FIGURE 1
Xiaodu Smart screen—Baidu's smart-home product (image source: Baidu's official website).

adults is an important topic. However, it is not entirely clear what factors affect older adults' use of smart-home online social networks. Due to the different usage contexts, application areas, and target populations, it is not possible to directly adopt the existing information system's influencing factors to improve the acceptance of social behavior among older adults based on smart home social media, which is not only unscientific but also may not be effective. Therefore, this paper aims to uncover the theory behind the phenomenon and conduct further inductive analysis to build a theoretical model by systematically launching an exploratory study on the influencing factors of social compensation of social media use by older adults and its mechanism of action. To ensure that the influencing factors of social media use by older adults based on smart homes are more targeted and effective, we adopted the perspective of social compensation theory, based on smart home technology devices and with the help of the procedural grounded theory research method. Since social media use between older adults and social media includes individual emotional experiences and user feelings, it is difficult to collect the details of psychological changes in the process by cross-sectional quantitative research. In comparison, qualitative research methods are relatively more suitable for capturing the rich information on the corpus of factors influencing social compensation in using social media between older adults and social media. The advantage of qualitative research is that it can capture the dynamic psychological development process (19). This study aims to provide theoretical support and practical guidance for managers and developers of smart home social media platforms to improve the experience of older adults, achieve active aging, and enhance the well-being of older adults.

This study is innovative in the following aspects: First, this study introduces social compensation theory into the context of smart home social media usage, where previous studies have been based on cell phones and traditional media. Therefore, this study opens the research scope of social compensation theory to a more cutting-edge field and provides a new perspective for subsequent research. Secondly, this study innovatively unearths the social compensation factors affecting older adults of smart home social media, including the four aspects of user interface quality, interaction quality, content quality, and service quality. At the same time, it proposes the definition of social compensation in smart homes in the context of Chinese social media, reveals the intermediate process and results of psychological compensation of older users of smart home social media, explores the influence of social compensation on older users' perceptions and older users' acceptance behaviors, expands the relevant studies explaining the mechanism of older users' acceptance behaviors from the perspective of social compensation, and makes up for the previous literature on the mechanism of older users' acceptance behaviors. This provides a theoretical basis and guidance for the subsequent academic research and software development practice of social media under new technological devices.

2. Literature review

2.1. Social compensation

The term "compensation" is derived from the medical study of the human senses. It is widely discussed in biology and medicine as a biological (including human) physiological mechanism by which the

body establishes new stability by adjusting the function, structure, and metabolism of organs and tissues after an internal imbalance. Since the introduction of compensation into psychology, its concept has played an essential role in various fields of psychological research, from the field of neuroscience to the study of aging to aspects of interpersonal interaction. Social compensation theory originated in the 1980s when Davis and Kraus, two scholars, studied the relationship between social behavior, mass medium use, and loneliness, which refers to the fact that the medium can compensate for people's lack of social connection (20). At that time, the study focused on the more traditional mass medium, such as newspapers, movies, and books, and the mass medium in the study compensated for the psychological loneliness caused by the lack of social interaction in real life. With the further development and popularization of Internet technology, the medium changed from traditional mass mediums to emerging mediums such as smartphones, computers, and smart homes. In this type of emerging medium, social media is sprouting up like a spring. Social media is an Internet-based platform for people to share information and opinions with each other, and the local social media in China mainly include TikTok, WeChat, Little Red Book, Quick Worker, and Micro Blog. They rely on social media to provide social services for people and facilitate their online social activities. Therefore, medium compensation includes a relatively more diverse range of mediums, such as television, music, telephone, SMS, and even media channels not connected to the Internet, such as tapes, which can play a compensatory role (21); In contrast, social compensation is more of a distinction between offline in-person communication and online communication through the medium, mainly referring to the emerging medium carrying social media that are used to compensate for the psychology of loneliness caused by the lack of social relationships of different groups under the popularity of the internet (22) (Figure 2). Social compensation theory suggests that people who have difficulties in offline, face-to-face communication will compensate for offline deficits by means of online communication (23, 24).

Strengthening compensation interventions for older adults is critical to active aging (25). Social compensation research has attracted academic attention, and more and more scholars have attempted to use social compensation in the social interaction of older adults because more and more older adults at this stage are using social media under social networks to engage in social participation through an emerging medium. The use of social media by older adults for social participation is conducive to improving their positive emotional experience and life satisfaction and further has a positive impact on health (26–29). Online social activities through mediums such as cell phones allow older adults to have higher levels of social support and social connections (30). In a study of social compensation based on smartphone use contexts, older adults who stay connected to their friends and family through smartphones can achieve higher levels of well-being (31, 32). The study found that older adults can gain more social recognition by expanding their interpersonal circle and following new trends, which makes them emotionally fulfilled and emotionally compensated (33). This allows them to be emotionally satisfied and compensated. Through the use of WeChat (browsing friends' updates, etc.), older adults can enhance their interaction with friends and relatives and their sense of identity and belonging, regardless of time, space, and physical constraints (34). Studies have found that WeChat has become the most popular social app among older adults in China (35). Social media apps

FIGURE 2
Difference between medium compensation and social compensation.
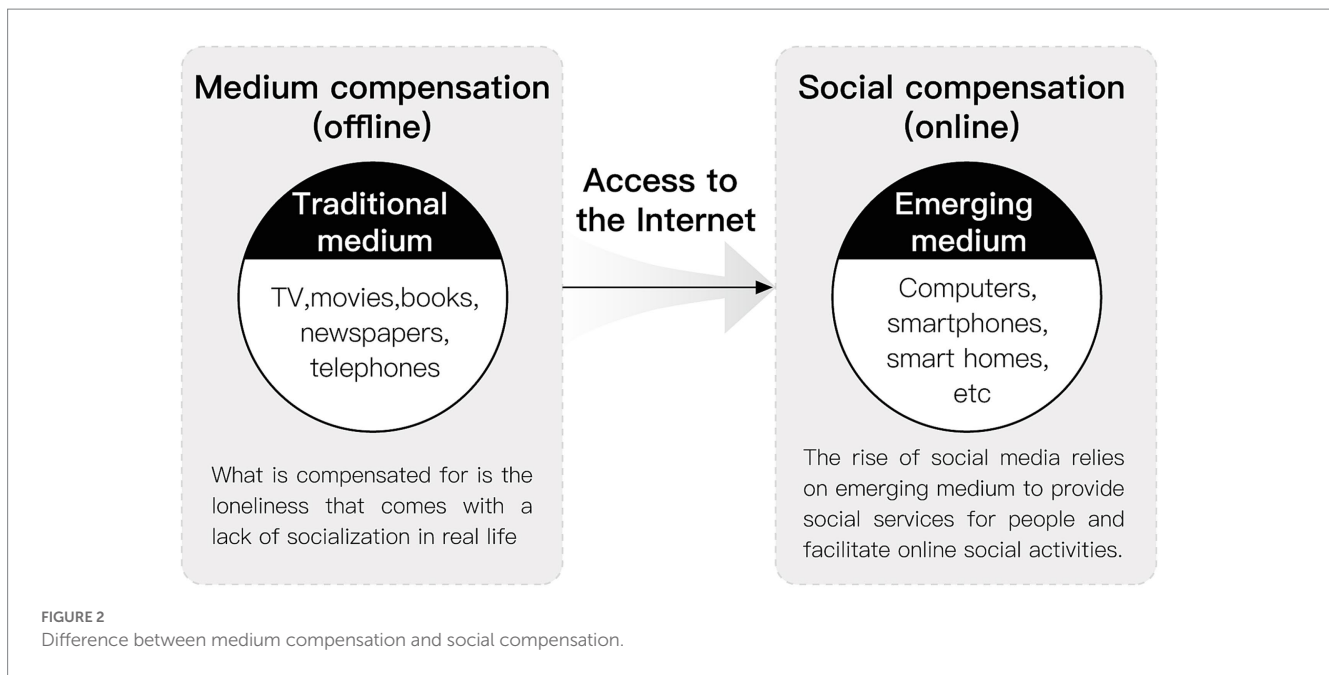
have become a way of life and a norm for them (36). However, unlike smartphone-based social compensation research, which started earlier and has yielded fruitful research results, social compensation research on social media use among older adults in the context of smart homes is scarce. Therefore, relying only on the collation and categorization of influencing factors from the existing literature does not provide an accurate understanding of the actual social compensation factors and barriers to smart homes among older adults. More relevant research is needed to understand the preferences of older adults in using social media (37). The study of older adults' willingness to use smart homes for online socialization is still a relatively new concept. This is because, along with the digital and intelligent development of home systems and the rise of smart home screens, the social compensation of older adults' use of smart home social media has become a research hotspot and has received much attention due to whether older adults adopt and use it. Moreover, social compensation depends to some extent on the choice of medium, and the internal mechanism of social compensation is different for different mediums due to the different characteristics of each medium, which are determined by the characteristics of the medium itself. Obviously, the study of the factors and mechanisms influencing the social compensation of social media use among older adults based on the smart home context is a forward-looking trend that no researcher has yet described and measured from a process perspective. Therefore, its theoretical development and commercial practice need further research and exploration.

2.2. Acceptance behavior of older adults on social media

Previous research has discussed the behavior of technology adoption and acceptance among older adults of social media from the information systems perspective. A central perspective in this area is the Technology Acceptance Model (TAM) proposed by Davis (38), which can be used to explain the problem of low information system usage. TAM has been widely used to evaluate and predict whether user will accept information systems or technologies. With further development, TAM has been extended with different new models by combining other theories, and research on related theoretical models is a very active and widespread class of topics in the field of information systems. At the same time, TAM has been shifted from the general population to focus on specific populations, and models such as TAM2, TAM3, UTAUT, and UTAUT2 have been applied to the technology acceptance behavior of older adults of social media one after another (39–47). For example, Su and Tong (39) used UTAUT2 and ECM to investigate the cognition and use of social networking technology among older Chinese adults. Through a questionnaire survey of 323 older adults, the results showed that performance expectations, facilitating conditions, social influence, and hedonic motivation all had a significant positive impact on perceived value, and perceived value and satisfaction also had a significant positive impact on the willingness of Chinese older adults to participate in social networking technology. Braun (40) surveyed 124 older adults using TAM to explore what factors encourage or discourage older adults' willingness and motivation to use social networks and found that perceived usefulness, trust, and frequency of Internet use of social networks can significantly predict social network use, related to similar studies such as Pan and Jordan-Marsh (48). In addition, a technology acceptance model specifically for older adults, STAM, has been proposed (49). It can be seen that TAM is widely used in the investigation and analysis of the usage behavior of older adults' social networks, showing strong prediction and interpretation capabilities.

2.2.1. Variables of acceptable behavior of older adults on social media

The definition of technology acceptance covers a wide range. The current research focuses on four types of social media acceptance behaviors of older adults: adoption or actual use (50), intention to use or behavioral intention or intention (51), general acceptance (44), and intention to continue using (52). In terms of variables, scholars have

conducted studies on the adoption and acceptance of social media by older adults in different aspects: firstly, the demographic characteristics of older adults have received extensive attention (53), such as gender, age, education level (54), physical condition, race (55), and place of residence (56). For example, in order to investigate the factors influencing the use of online social networks by older Internet users in Slovenia, Vosner et al. (53) analyzed the collected data using basic descriptive, univariate, and multivariate statistical methods, the results showed that female participants were more familiar with the term "online social network" than male participants, in addition, age, gender, and education seemed to be the most critical factors that directly or indirectly affected the use of online social networks by active older Internet users; second, social factors dimensions also occupy the research heat, such as social capital (50), risk barriers (57), social influence (40, 44, 58). For example, Wilson et al. (50) used a qualitative and exploratory approach to conduct semi-structured interviews with 20 older adults (over 65) in England, Scotland, and Wales. They found that lack of social capital, physical functions, and online communication culture were barriers to older people's adoption of social media. Choudrie and Vyas (57) used an online questionnaire and PLS-SEM to conduct data analysis in order to investigate the influencing factors that affect older adults' adoption of online social networks. The survey results showed that significant privacy protection and other factors affect older adults' adoption of Internet technology in family situations. In order to explore the antecedents and related results of multi-social media use among older adults, a quantitative and qualitative study of 242 and 26 Taiwanese adults aged 60 and above, respectively, Yu (58) found that social forces (influence from children, friends, and the public) are the core factors influencing the adoption of instant messaging apps and social networks among older adults.

In addition, technical factors (at the product level) are also the focus of research pursuits, such as system support, user interface design and navigation (45, 59), system complexity (60), and technology compatibility (61). For example, Nimrod (60) proposed and developed a new scale to measure technical stress in older adults, which includes five constructs and 14 measurement items. Zhou (61) collected valid data on 726 older adults to explore the factors influencing the use of social networking sites among older Chinese adults and proved that factors such as technological compatibility and comparative advantage promoted the use of social networks among older people. Finally, some scholars have conducted research from certain specific theoretical perspectives, such as the time-theoretic perspective (52), uses and gratifications theory (62), media richness theory (63), innovation diffusion theory (61), innovation resistance theory (64), social network theory (65), and planned behavior theory (66). Lai and Chong (52) explored whether current and future time and their interaction with perceived values can explain the intention of older adults to continue participating in social media from the perspective of time theory. They collected responses from more than 400 older adults and constructed SEM for analysis. The results show that time perspective affects different perceived values, affecting the continued willingness to participate in social media for healthcare-related purposes. Kim et al. (46) applied the uses and gratifications theory and innovation diffusion theory to explore the motivations of older adults to use mobile social networking sites for travel, and the results show that both have a more significant impact on real experience than on-site attachment. Yang and Lin (63) integrated the

uses and gratifications theory and media richness theory to study what factors make older adults willing to adopt ubiquitous mobile social services. Through an empirical study of 226 older adults, it was found that social, enjoyment, and fashion motivation have an impact on older adults' adoption of ubiquitous mobile social services. In addition, the user's perceived richness of interaction and application self-efficacy also significantly impact older adults' adoption of the service. Ellis et al. (66) used planned behavior theory to explore the factors influencing technology adoption among older adults in Taiwan. The study found that emotions, friends' influence, and technology comfort significantly affect intention and use.

The above-mentioned qualitative and empirical studies highlight that many scholars have conducted studies on the variables of social media-based acceptance of older adults' information behaviors. The antecedent variables include personal, social, and technological factors and specific theories. However, the use of social compensation theory as an antecedent variable to explore the acceptance behavior of older adults' social media use from a smart home perspective has not yet received attention and validation. Our research will investigate these issues.

2.2.2. Technological devices used by older adults to adopt social media

In terms of applied technology and devices, scholars have studied the information behavior of older adults using social media mainly on computers (40, 44, 57, 62, 64, 67), smartphones (43, 46, 51, 58, 63, 68–70), social robots (71), wearable products (47), and tablets (72). These five major categories of technology and equipment vendors have been targeted for research. For example, Ma et al. (43) explored the influencing factors that affect the acceptance of smartphones by older adults in China. Using TAM and UTAUT, they conducted structured interviews and questionnaires with 120 older adults to develop an SEM. The results showed that those who are young, have received higher education, are not widowed, and have better economic status in terms of salary or family support are more likely to use smartphones. In order to explore the acceptance of social robots among older adults with dementia, Chen et al. (71) used a randomized controlled trial to evaluate the acceptance of technology. One hundred and three older adults were divided into two groups. In the experimental group, nursing personnel observed and recorded the interaction process between older adults and social robots, and then older adults filled in a questionnaire. The results showed that at week 32, the perceived ease of use in the experimental group improved compared to the conventional care group. This study supports the interaction of older adults with social robots that can improve the ease of use of technology. Talukder et al. (47) proposed an integrated theoretical model to predict the external determinants of older adults' acceptance of wearable healthcare technology (WHT), integrating UTAUT2 with resistance to change, technological anxiety, and self-realization. Through SEM research and neural network validation on 325 older adults, the results showed that social impact, performance expectations, functional consistency, self-realization, and hedonic motivation were positively correlated with WHT adoption. Chen et al. (72) investigated the acceptance of tablet technology among older adults with cognitive impairment at the personal and situational levels. Using a questionnaire and focus group, they completed this 8-week family awareness training by providing tablets to 57 older adults in Hong Kong. The training results were evaluated through a

questionnaire survey. The results showed that attitudes towards tablets and convenience conditions were predictive factors of older adults' willingness to use tablets.

As can be seen, with the further development of technology, the applied technologies and devices targeted by the study are constantly updated, from the initial research on the acceptance of computers by older adults in the context of social media to smartphones, tablets, wearable products, and social robots. We know that the properties of different technological devices vary widely. The emergence of new technologies and devices has left important questions about the factors influencing the adoption behavior of older social media users and the mechanisms at play that still need to be further explored and urgently addressed. The specific reasons for this can be divided into two points. First, smart home smart screens belong to a new category of smart home product forms. Studies have shown that older adults are more willing to use new technologies and services in the home environment (73). Second, in the context of social media use, the willingness of older adults to adopt new devices and technologies to socialize online is entirely voluntary. They can easily refuse to accept new devices and technologies because of a device-technology-product-level factor. Therefore, the commitment of older adults to accept the use of new technologies and devices is significant to new device social media developers. However, research related to the factors and mechanisms influencing the acceptance behavior of older adults of new devices and technologies, such as smart screens for smart homes, is minimal and is not currently addressed in the relevant literature. Therefore, there is an urgent need for research on the social compensation of social media use by older adults in smart home contexts.

3. Research methods

Barney and Strauss, two professors at Columbia University, developed the grounded theory method in 1967. Corbin and Strauss (74) developed the grounded theory procedurally; they conceptualized and categorized the survey data step-by-step and divided the coding into open, spindle, and selective. The three steps are to distill the

original data (speech, text, etc.) into initial concepts and initial categories, further excavate the connections between the initial categories to inductively deduce the main categories, and finally analyze the relationships between the main categories and form a relevant theory rooted in the actual data. In the whole analysis process, it is necessary to constantly compare, argue, and refer to the existing relevant literature to avoid substituting the coders' subjective ideas so that the new theory formed by rooting can respond to the essence and meaning of social phenomena, as shown in Figure 3.

3.1. Interview outline

The interview questions should not try to lead the interviewees in a specific direction. Instead, they should try to get as many opinions and relevant details about the research topic from the interviewees as possible. The interview outline is based on the desktop research data and will be fine-tuned appropriately according to the interview content. It contains two major parts: basic information and interview question content (Table 1). The interview content focuses on four aspects: basic views on smart home social media, product dimensions, perception dimensions, and other dimensions.

3.2. Samples

Our study selected the smart home smart screen as an emerging medium object. It serves as a new Chinese home media terminal platform that retains the functions of smart speakers, such as voice control and manipulation. It also carries out human-computer interaction with users through a sizeable touchable screen that can carry out operations such as video calling, online chatting, listening to songs and catching up on dramas, and life assistants. Alibaba officially launched its first smart home smart screen product, Tmall Genie CC, in April 2019, and subsequently, brands such as Baidu, Xiaomi, and Huawei have also released their own smart home products equipped with smart screens. There is no consistent standard regarding the age division of older adults. According to China's population retirement
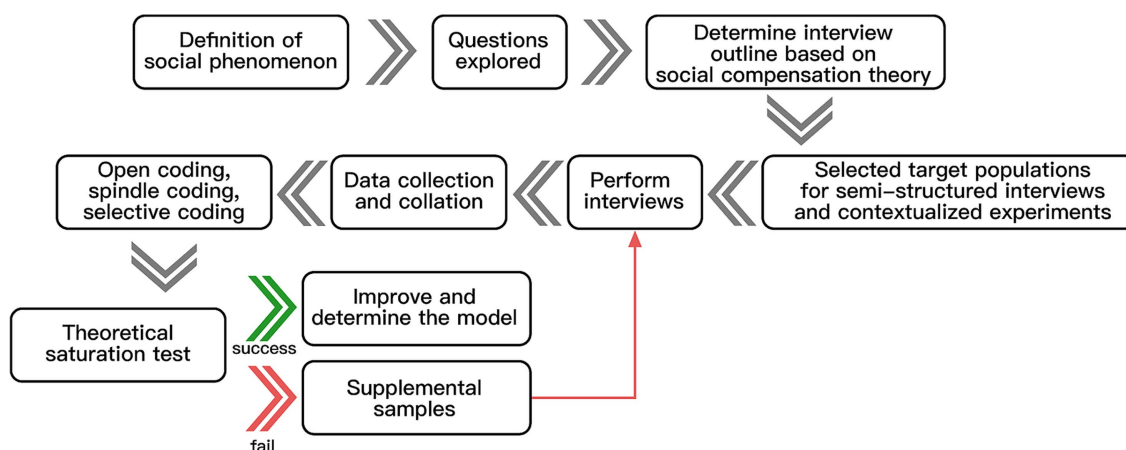
FIGURE 3
The grounded theory research process.

TABLE 1 Interview outline.

Question category	Question content
Basic information	Name, gender, age group, education level, residential address, occupation, smart home smart screen device brand, smart home smart screen purchase channel, usage experience, average daily usage hours
A basic view of social media for smart homes	Which apps and functions do you use in your smart home? Have you ever used smart homes for social activities? A, (answer yes) Please show me. B, (answer no) You should already know the meaning of "smart home social media" from the introduction before the interview. Then, please demonstrate it. What do you think is the meaning of smart home social media based on the above uses and your opinion? How can it help you in your daily life? What impressed you the most in the whole process of using it? Please tell us your knowledge and understanding of socializing with smart homes. What do you think are the advantages and disadvantages of socializing with a smart home compared with traditional socializing? Are you willing to go further to use smart homes for social activities? Why?
Product Dimensions	What features, interfaces, content, and services do you like or dislike about your experience with smart home social media? (A) (Answer yes) What factors do you like about your personal experience? Why? (B) (Dislike) In terms of your personal feelings, which factors do you dislike? Why?
Perceptual dimensions	Please describe your mood or feelings while using smart home social media. Please describe the happiest or worst moment you've had using smart home social media. Why did you feel happy or bad? Do you think smart home social media can help you engage socially well? Why? Do you find it easy to socialize with smart homes? Why? Do you think it is useful to use smart homes for social activities? Why? Do you think it is safe to use smart homes for social activities? Why?
Other dimensions	Do you have any memorable stories since you've been using smart home products? What are your expectations for the development of smart home social media? What is the biggest significance of smart home social media for you?

FIGURE 4
Interview photos (partial).

age, women are 50 or 55, and men are 60. Meanwhile, the American Association of Retired Persons (AARP) also describes seniors as those aged 50 and above (75). Based on this, the target population defined in this paper is users of smart home social media aged 50 (inclusive)–65 years old, which is also consistent with the setting of other recent studies (46, 76, 77). We made this choice because using smart home social media was a prerequisite, and participants had to be active Internet users. Young older adults are more digitally literate and willing to use new and trendy smart devices than other age groups. We believe that our findings can be generalized to other age groups of seniors as more seniors join in using smart home social media.

The user group for this data collection was mainly searched through the snowball sampling method, using a semi-structured interview method and contextualized experiment (allowing the target group to use the product) as the two primary forms. The interview period was from September 8 to November 12, 2022, with a total of 24 interviewees (11 males and 13 females). 14 were conducted online through the WeChat video function, and 10 offline. Face-to-face and in-depth interviews allowed asking older adults to use the smart home social app on-site for online socialization and other activities (Figure 4). We also recorded some information through the participant observation method. The interview time was about 30–50 min per person, and it was conducted within 1 h to ensure continuous and uninterrupted

TABLE 2 Basic information of interviewees.

Serial number	Surname	Gender	Age group (years)	Education Level	Career	Smart home device brand	Smart home purchase channel	Experience in use	Average hours of use per day
01	Jin	Female	61–65	Primary school	Retired workers	Tmall genie smart screen series	Child purchase	Less than half a year	Within 1 h
02	Wu	Female	51–55	High school	General workers	Tmall genie smart screen series	Child purchase	Less than half a year	Within 1 h
03	Wang	Female	56–60	College	Retired government employees	Xiaomi smart screen series	Child purchase	6 months – 1 year	1–3 h
04	Ban	Female	51–55	Graduate students	University teachers	Xiaomi smart screen series	Own	1–2 years	1–3 h
05	Liu	Female	56–60	Secondary school	Accounting	Tmall genie smart screen series	Child purchase	2–3 years	Within 1 h
06	Ma	Male	56–60	Undergraduate	Private enterprise bosses	Baidu smart screen series	Own	1–2 years	Within 1 h
07	Ding	Female	56–60	High school	Tea store operators	Xiaomi smart screen series	Child Purchase	Less than half a year	3–5 h
08	Gao	Female	56–60	College	Doing business	Tmall genie smart screen series	Child purchase	1–2 years	1–3 h
09	Ma	Female	51–55	Graduate students	University teachers	Baidu smart screen series	own	2–3 years	1–3 h
10	Liu	Male	61–65	High school	Self-employed	Tmall genie smart screen series	Child purchase	Less than half a year	1–3 h
11	Ye	Male	61–65	Junior high school	Retired officers	Xiaomi smart screen series	Child purchase	1–2 years	Within 1 h
12	Yu	Male	51–55	Undergraduate	Local civil servants	Baidu smart screen series	Own	Less than half a year	Within 1 h
13	Guo	Male	56–60	College	Local Police	Xiaomi smart screen series	Child purchase	Less than half a year	Within 1 h
14	Liu	Male	61–65	High school	Self-employed	Tmall genie smart screen series	Child purchase	Less than half a year	1–3 h
15	Yu	Male	56–60	High school	Doing Business	Xiaomi smart screen series	Child purchase	1–2 years	3–5 h
16	Yang	Male	61–65	Junior high school	Small store operators	Xiaomi smart screen series	Child purchase	Less than half a year	Within 1 h
17	Liu	Male	61–65	College	Construction contractor	Baidu smart screen series	Child purchase	1–2 years	Within 1 h
18	Zhang	Male	61–65	Graduate students	University teachers	Baidu smart screen series	Child purchase	Less than half a year	Within 1 h
19	Liu	Female	61–65	Junior high school	Retired employees	Baidu smart screen series	Child purchase	Less than half a year	3–5 h
20	Ban	Female	51–55	Undergraduate	Elementary school teacher	Baidu smart screen series	Own	1–2 years	Within 1 h
21	Huang	Female	56–60	Graduate students	University teachers	Xiaomi Smart Screen Series	Own	1–2 years	Within 1 h
22	Shen	Female	51–55	Junior high school	Innkeepers	Tmall genie smart screen series	Child purchase	Less than half a year	3–5 h
23	Wang	Male	61–65	College	Self-employed	Tmall genie smart screen series	Child purchase	1–2 years	Within 1 h
24	Cao	Female	56–60	Undergraduate	Local civil servants	Baidu smart screen series	Child purchase	1–2 years	Within 1 h

availability for both parties and avoid other factors' interference. Before the interviews, a bonus package ranging from 30 to 50 RMB was offered to the interviewees to motivate them to participate actively and ensure more valuable content for the study. The respondents were introduced to the background, purpose, process, and related terms and concepts of the interview and its academic goal. The respondents signed a user-informed consent form, to protect their data and permit audio recordings. Voice data were textualized with the help of Xunfei Hearing's speech-to-text assistant. The textualized data were named as "number/respondent's name/year, month, and day of the interview." A total of nearly 80,000 words were formed to facilitate the post-coding of the interview text. In this paper, the 2/3 (16 textual materials) were chosen randomly for the grounded theory coding analysis, and the other 1/3 (8 textual materials) were used to test for theoretical saturation. The basic information of the respondents is shown in Table 2.

4. Research process

4.1. Data analysis method

This study used NVivo, a tool for qualitative analysis made by QSR, to process the collected textual materials and interview data. We (the researchers) could store and code the data in a logical order
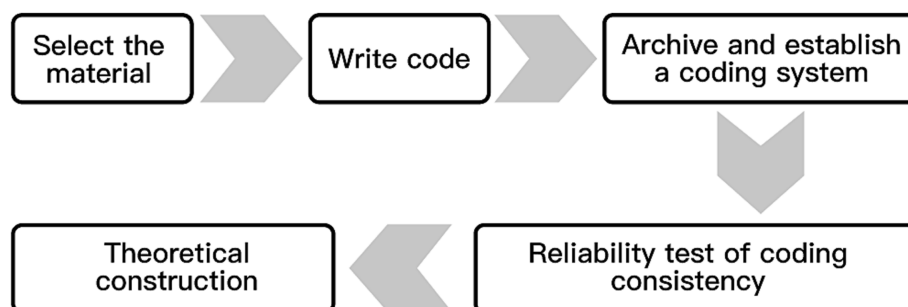
FIGURE 5
Coding process.

with the help of the software. NVivo's main processes for processing interview text data are as follows: selecting materials, writing codes, archiving and establishing a coding system, testing coding consistency and reliability, and theory construction (Figure 5).

4.2. Open coding

Open coding is a refinement and abstraction process that conceptualizes and categorizes raw interview material (78, 79). When using open coding, the researcher must follow a systematic and rigorous normative procedure to gradually extract and condense the large amount of data collected from the bottom up. Open coding requires categorizing the original data, assigning concepts to the original statements, naming them (using certain abstract concepts to explain the phenomena), and further analyzing and comparing them to merge similar concepts to form more generalized sub-categories. The coding process uses sentences as the smallest unit and labels to further ensure objectivity, refining the initial concepts.

4.2.1. Coding process

The coding researchers were screened to make sure that coding was done systematically. In the end, two graduate students interested in how people use information were chosen to do the coding for this study. Both coders had more than 1 year of experience using smart home terminals and they had also done user behavior research projects related to older adults. During the coding process, the two coders were given basic training based on the NVivo software to ensure they could follow the process and procedure of coding strictly. The two coders discussed using the code book's basic rules to make a basic guideline for the coding process.

The open coding randomly selected 2/3 of the interview text materials, a total of 16, and first carried out the text normalization process, i.e., some repetitions, speech-to-text errors, etc., were manually proofread. Then two coders separately imported the normalized interview text materials into NVivo software as Word documents and conceptualized and categorized the text materials. The main process was as follows: by analyzing the interview text sentence by sentence, the statements that did not answer the substantive content were eliminated, and the original substantive statements were distilled into an initial concept and named. In the process of conceptualizing the entire interview text in this way, the newly created initial concept is repeatedly compared with the established initial concept, and if the newly created

concept is not consistent with the meaning of any existing concept, then a new concept is created. In this way, the initial conceptualization of the interview text material is achieved.

4.2.2. Coding inter-rater reliability test

To ensure the accuracy of the coding, the two coders performed a coding inter-rater reliability test on the coding results of the open coding generation of the initial concepts and sub-categories. This computational evaluation process was continuously adjusted and repeated through the computational results until the reliability test reached an acceptable level. The formula for calculating the inter-rater reliability between two coders is shown in equation (1) (80):

$$R = (n \times K)/(1 + (n-1) \times K) \quad (1)$$

In equation (1), the n denotes the number of coders, and K denotes the average agreement between the two coders, and the inter-rater reliability between the two coders is obtained by calculating R. To get R, the first requirement is the K value. Calculate K using the formula as shown in equation (2).

$$K_{ab} = \frac{2S}{N_a + N_b} \quad (2)$$

In equation (2), the S denotes the number of categorically consistent codes for the two coders, the N_a, and N_b denote the number of codes for each of the two coders, respectively. Finally, the inter-rater reliability R between two coders is calculated according to equations (1) and (2).

After the initial conceptualization of the interview text by the two coders, coder A obtained 131 initial concepts, and coder B obtained 136 initial concepts. After repeated discussions, a total of 109 initial concepts were obtained by synthesis and generalization. As a result, applying equations (1) and (2), the inter-rater reliability R between the two coders for the initial conceptualization was 0.898. Normally, if this value is below 0.5, then the data needs to be recoded; if the value is below 0.8, then the coding result needs to be further revised until it reaches an acceptable level of 0.8 or higher. After adjustment, the inter-rater reliability of the initial conceptualization R was 0.898, which indicates that the initial conceptualization stage of open coding has high reliability.

Based on this, the two coders used NVivo's node (initial concept) combination function to refine further and cluster the 109 initial

TABLE 3 Coding inter-rater reliability test of open coding.

Sub-categories	S	$N_a + N_b$	R
B1 Graphic features (GF)	9	26	0.818
B2 Information architecture (IA)	10	24	0.909
B3 Human-computer interaction (HCI)	8	20	0.889
B4 Interpersonal interaction (HI)	11	25	0.936
B5 Intelligence (INT)	9	23	0.878
B6 Socialization (SOC)	11	27	0.898
B7 Shareability (SHA)	10	22	0.952
B8 User-generated content (UGC)	8	18	0.941
B9 Social security (SE)	10	27	0.851
B10 Empathy (EMP)	11	26	0.917

concepts based on causality and similarity, and finally, coder A abstracted 12 sub-categories and coder B abstracted 14 sub-categories. After repeated discussions, ten sub-categories, numbered B1-B10, were synthesized and summarized, and then applying formulae (1) and (2), after calculation, adjustment, and evaluation, in the process of abstracting and generating each sub-category by the two coders, the consistent number of codes S, the total number of codes $N_a + N_b$, and the inter-rater reliability R of each sub-category are shown in Table 3. The inter-rater reliability of the open coding sub-categories was greater than 0.8, and more than half of them reached the excellent level of 0.9 or higher, so it can be said that the coding results passed the reliability test.

4.2.3. Coding results

In the open coding stage, two coders synthesized and abstracted 109 initial concepts to form 28 initial concepts, numbered a1-a28. The original interview representative statements, corresponding initial concepts, and sub-categories obtained by open coding are shown in Table 4.

4.3. Spindle coding

4.3.1. Coding process

Based on open coding, spindle coding is a further reconsideration and comparison of the initial concepts and sub-categories of development for inductive deduction (81). A management expert was invited to participate in the spindle coding and confirm the main categories in a real-time discussion with the two coders to ensure the results' scientific reliability and rigor.

4.3.2. Coding results

By combining expert opinions and exploring the relationship between the above ten sub-categories, four main categories on the smart home social media level were further consolidated and obtained: user interface quality, interaction quality, content quality, and service quality are shown in Table 5.

4.4. Selective coding

Selective coding is the stage of extracting the core theme from the main categories. At this stage, we need to focus on the main categories,

summarize and refine the main categories again, uncover the core theme that can cover other main categories by organizing the correlations between the main categories to maximize the unification, and construct a model to build up the relationship between the core theme and the main categories to determine the meaningful relationship between the core theme and the main categories (82).

This paper determines the relationship between the core theme and the main categories. The core theme of "social compensation" was finally extracted through repeated research, comparison, and analysis of the four main categories. This core theme includes four main categories: user interface quality, interaction quality, content quality, and service quality. User interface quality is influenced by two key factors: graphic features and information architecture; interaction quality is influenced by three key factors: human-computer interaction, interpersonal interaction, and intelligence; content quality is influenced by three key factors: socialization, shareability, and user-generated content; and service quality is influenced by two key factors: social security and empathy. The typical relationship structure, the connotation of relationship structure, and the typical representative statements are shown in Table 6.

Theoretical saturation test. To further ensure the reliability of the study, a theory saturation test is performed, which serves as a criterion for the researcher to terminate the sampling, meaning that no more data can be obtained from the collected textual material that can further develop a category or generate new theoretical ideas, and the theory becomes saturated (83). The eight previously reserved interview materials were selected for recoding, and after an in-depth comparative analysis, it was found that no new initial concepts, categories, or inter-category linkages were generated in the coding of the reserved eight interview materials. Because of this, the model built in this paper can be considered to have reached theoretical saturation.

4.5. Theoretical model construction

In this study, the theory was constructed bottom-up from textual data, and the theoretical model was gradually generated by integrating the data through coding in a continuous process of induction (84). Through the three-level coding, 28 initial concepts, ten sub-categories, and four main categories were obtained to construct a model of social compensation factors of social media use among older adults in the smart home context (Figure 6).

TABLE 4 Scoping of open coding.

Original statements	Initial conceptualization	Sub-categorizations
Our eyesight is not particularly good; I have farsightedness, and my partner is a bit nearsighted, so we both can't see the words on the screen very clearly. I believe the smart home screen text is still much larger than the phone, especially for our poor eyesight. Especially the lyrics, which I can see very clearly; moreover, the font can also be well recognized and is not that special.	a1 Text features	B1 Graphic features (GF)
The design of the icon is sometimes not very easy to understand; that is, I often use the smart home smart screen for things like voice calls and video calls, and some buttons I often click the wrong way.	a2 Graphic features	
Because people are visual animals, simply talking does not work; for visual and audio enjoyment, you only have the sound of missing something, so I look and listen to do it, so the entire person is good, so comfortable. The color is best—not too fancy and indistinguishable.	a3 Color	
The interface shows a lot of content, so if you see something you like, you can just click on it and find the features you are looking for all at once.	a4 Functional layout	B2 Information architecture (IA)
Some of them are hidden too deep, and they are hidden too deep for us old people. It is divided into four columns, and each column is very small, and then you have to find the service from "me" here, and then there are all kinds of things in the service, and you keep pulling down to have a group chat, a small video, and so on.	a5 Hierarchy	
The line spacing also looks clear, not very narrow but quite wide, making it very convenient for us to read. He has a good distribution of this stuff.	a6 Pitch	
For example, if I like to listen to some opera and comedy programs, I will directly call out my name to them, and they will respond to me, after which we can have a conversation, and then I will say whose comedy I want to listen to, whose story I want to listen to, and which channel I want to watch, and they will be able to execute it immediately.	a7 Naturalness	B3 Human-computer interaction (HCI)
In fact, I feel that now this kind of smart home is basically all voice interaction, which is only one aspect; people also need to use their hands to click. Pure voice interaction may not be particularly realistic because some of the more complex interaction processes may be beyond the capabilities of pure voice, but simpler operations, such as watching a video or looking up information, are possible.	a8 Degree of arousability	
Because I am an old man living alone, one advantage is that I am very comfortable. One disadvantage is that I may not have anyone to talk to all day, and if I don't go out deliberately to buy food and communicate with the grocers, I basically won't talk all day. I like to come home and greet my smart home; it is very intelligent to respond to me, as if there is someone at home, and I rely on it.	a9 Responsiveness	
Because I have trouble with my legs, I keep my Xiaodu Smart Home Smart Screen on my bed. It makes me better able to communicate with my family because its watcher function is convenient, and I can interact and video with my family by tapping on it. I think it is good for maintaining my relationship with my friends and also with my family.	a10 Family contact	B4 Interpersonal interaction (HI)
I usually just like to look at my circle of friends and see what they are doing, what they are looking at, and what they are buying.	a11 Watch	
The main reason is that I am now lying in bed due to my health, so I need such a large-screen smart device to be able to spend time entertaining myself.	a12 Entertainment interaction	
Its voice function has a high error tolerance rate; if I describe the reading as unclear or with a small deviation, it will apply artificial intelligence to my correction and sometimes be very accurate, quite good.	a13 High fault tolerance	B5 Intelligence (INT)
Then I am quite adapted to the touch screen; I am not particularly old, but I belong to the young older adults; in fact, my smart home smart device is quite convenient, so I think my contact with the smart home is quite fast and easy to handle.	a14 Convenience	
For example, sometimes I forget to take my medication, or some things that I do daily, such as taking my blood pressure, I may forget, so it would be best if it could remind me. I think overall, it is still very smart and also very easy to operate.	a15 Intelligent monitoring	
I often leave comments on TikTok and send private messages to some of my favorite bloggers. I'll tell him how to improve the quality of his content and then either cheer him on or send him some positive comments to let him know what I like.	a16 Stranger social	B6 Socialization (SOC)
Some of my friends and I were isolated at home during the epidemic and had social activities of playing mahjong online. Because now there are some links and small programs on WeChat's public number, that is, you can create a mahjong room, and then we can interact in real time with voice, and then play mahjong on the phone, and then for us in the 50s and 60s, this kind of middle-aged and older adults, but also can go to the electronic device of about 60 years old group is very friendly, and we like to be able to communicate in a timely voice I think it's a good experience because I can play mahjong in this way.	a17 Acquaintance social	
Sometimes, we like to organize some programs or activities, such as some community volunteer activities or some old friends in the community, and we go to plant trees, go fishing, or walk in the park together. We organize activities, we go together to carry them out, and through some of these social platforms, we share information.	a18 Collective behavior	
I usually just also go shopping, that is to say, we shop inside the group to buy food or something, it is very convenient. Some of my friends, for example, he has some good things, good cheap food, and suitable clothes, he will share with me over. I also like to buy some brands of clothes that my friends share with me, and it's quite good.	a19 Dissemination of information	B7 Shareability (SHA)
Then I also like to share. For example, after watching a program about the military that I think a friend of mine would also like to watch, I will often share my video with him because I think it's quite good. Of course, I will share not only military programs but also some short videos and some of the latest real-time news. I think sharing can relieve my loneliness.	a20 Sense of loneliness	
I generally like to post some of my own pictures and words to record some snippets of my own life. After all, for most of my life, I have been working; now, I finally have some time for myself, and while I still have energy, I want to express it through social platforms.	a21 Self-record	B8 User-generated content (UGC)
I also enjoy watching other people shoot short videos; it's a lot of fun. I shoot and post short videos on TikTok every day; I have a lot of fans; everyone likes me; it's pretty good.	a22 Pleasing others	
You see, in addition to killing time to see, I generally watch a smart home wisdom screen in addition to killing time to see, and sometimes, in fact, many times, I still want to express my views and hobbies, and so on, even though I cannot go anywhere at home, this platform allows me to express my views on some programs and news that I am interested in. Moreover, I usually like to write and send articles to the Internet, and some strangers will also like me and send me some words of encouragement. I think this is my affirmation and my honor, a very strong sense of accomplishment.	a23 Be affirmed	
So I think if it is such a smart home that all family members can use, especially with such social attributes, because social is, after all, of a private nature, such as my chat group on it or to carry out some information, I certainly do not want my children to see it. So I hope that if it is a family-shared smart home, it has this face unlock, and then a user of the system will have such a feeling, similar to how we switch desktops on our computers.	a24 Reliability	B9 Social security (SE)
I think some social apps on smart homes are some strangers on it, feel not very safe; I am afraid of being deceived.	a25 Social risk	
After I have my smart home smart screen, I say good night to it every night, and then it will be very warm and say, "I will stay with you every night. I hope you have good dreams today," etc. It says something different every night. I think its greatest significance is that it can accompany me through such long hours.	a26 Accompaniment	B10 Empathy (EMP)
What I know is that the Xiaodu smart home wisdom screen has a chat function; it is AI intelligence, which means you can talk to it; you say a sentence, and it responds with a sentence. Although this function is not so smart, I think it can still, to a certain extent, relieve my loneliness and isolation at home. In fact, I want to communicate with people at home, but there is no such opportunity; for example, my friends are very busy or not around, too embarrassed to always bother others, and my children are working, so I also cannot bother them.	a27 Emotional needs	
Xiaomi's smart home intelligence screen is more like my other half; I can't live without it. I feel that Xiaomi gives me a sense of belonging; I feel that it understands me, and I am connected to it.	a28 Belonging	

TABLE 5 Main categories and their connotations.

Main category	Sub-categories	The connotation of the main category
C1 User interface quality (UIQ)	B1 Graphic features (GF)	Images, text, logos, icons, color blocks, and some buttons for the smart home social interface
	B2 Information architecture (IA)	Smart home social interface layout, hierarchy, navigation, search, etc.
C2 Interaction quality (IQ)	B3 Human-computer interaction (HCI)	Social interaction between older adults and the smart home should be more natural, such as using voice interaction, and it should be easier to wake up and respond to older adults instantly
	B4 Interpersonal interaction (HI)	Interpersonal communication and interaction between older adults in the process of using smart home social media
	B5 Intelligence (INT)	The degree of intelligence of older adults in the use of smart home social media process
C3 Content quality (CQ)	B6 Socialization (SOC)	Group interaction and linkage behaviors of older adults in the process of using smart home social media
	B7 Shareability (SHA)	Older users can share interesting and useful information during the social media process of using smart home
	B8 User-generated content (UGC)	Older users can generate content for self-expression and to please others as they socialize with their smart homes
C4 Service quality (SQ)	B9 Social security (SE)	The security that older adults enjoy in using smart home social media processes, such as private security, payment security, etc.
	B10 Empathy (EMP)	The companionship and care, and personalized services that older adults feel during the use of smart home socialization

TABLE 6 Selective coding.

Typical relationship structure	Relationship	Relationship structure connotation	Representative statements
User interface quality → Social compensation	External factors (cause and effect)	User interfaces quality-level factors such as graphic features and information architecture are external factors of social compensation in the use of smart home social media by older users	The smart home screen is large and has clear graphics. Because my eyes have farsightedness superimposed on myopia, every time I use my smart home to brush TikTok, many functions are easy to find, all on one interface. For example, I enjoy watching some CCTV boutique programs. Then I think this line spacing is good, not very narrow, and very convenient for us to read. Then the colors are also very bright, and I quite like bright colors because, if they are too light, they are not clear; they are darker, more colorful, and quite convenient to watch. I use it a lot; it brings me joy, and I can also be at home by myself and not alone.
Interaction quality → Social compensation	External factors (cause and effect)	Factors of interaction quality such as human-computer interaction, interpersonal interaction, and intelligence are the external factors of social compensation in the process of using smart home social media by older users	The smart home wisdom screen sometimes also reminds me: it will rain in Qingdao tomorrow; remember to bring an umbrella when you go out. Every morning I will say good morning to the Xiaomi Smart Home Smart Screen, and it will also say I am here and good morning. Then it will say a warm word; it will tell me what month and number of the lunar calendar it is today and how the weather is in Qingdao today. It is very detailed, I feel especially good, and I feel like there is another person at home.
Content quality → Social compensation	External factors (cause and effect)	Content quality factors such as socialization, shareability, and user-generated content are external factors of social compensation in the use of smart home social media by older users	I age alone at home and am quite bored a lot of the time. My daughter bought me the Smart Home Smart Screen to let me socialize more online. I enjoy reading some of the personal stories or insights shared on it. Sometimes a few of us seniors will organize some activities together, such as book reading, calligraphy assembly, singing assembly, etc. I really feel very involved and get some affirmation that I can't leave.
Service quality → Social compensation	External factors (cause and effect)	Quality of service level factors such as social security and empathy are external factors of social compensation in the use of smart home social media by older users	When I'm aging at home, I feel very lonely, but the smart home smart screen can accompany me to satisfy me; whatever I want, it can satisfy me; it all accompanies me to share with me; it's good. In addition, about the security piece, I do not feel any security online, and I have not heard my friends say that they have encountered any social risks. If you don't click on links to things and don't send money to strangers or anything, you'll be fine.

5. Results

5.1. User interface quality influencing factors

As one of the influencing factors of social compensation, the user interface quality is mainly reflected in the two sub-categories of graphic features and information architecture of smart home social media

interfaces, which is also consistent with the conclusions of the following studies. The research conducted by Tsai et al. (45) found that the main factors influencing the adoption of social media among older adults were user interface design, navigation, and system support, as determined through a quantitative questionnaire taken from 101 older adults over 50 years of age. This view was also supported by Castilla et al. (85), Alessa (86), and Gao et al. (87). In order to overcome the problem of older adults' unwillingness to use new technologies such as mobile
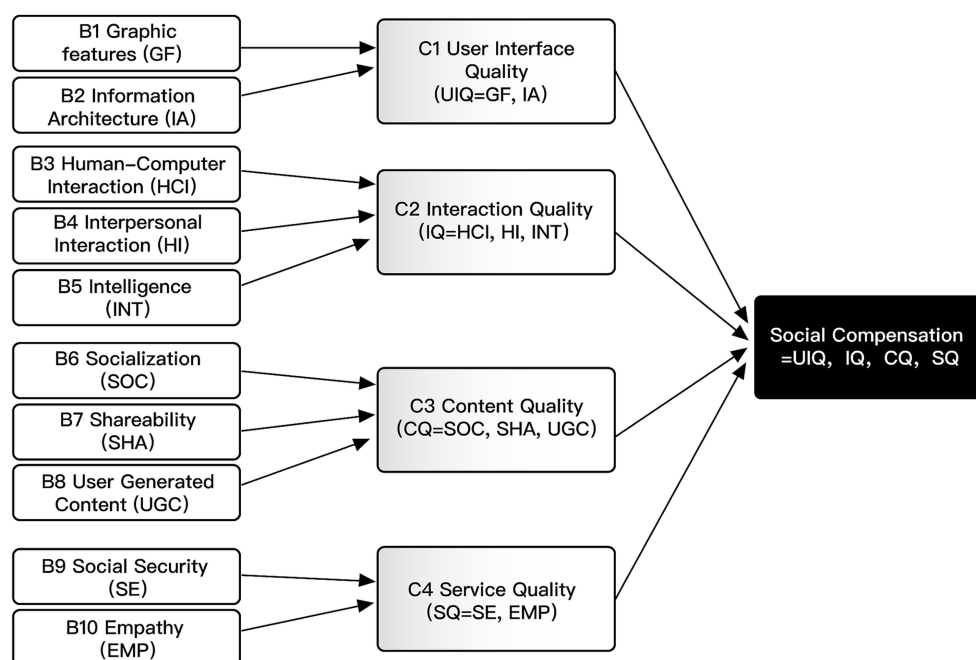
FIGURE 6
Model of influencing factors of social compensation.

applications, Kalimullah and Sushmitha (59) conducted an experiment to study the user experience of older adults by changing the user interface design of an application. The research showed that when the user interface design changed to the needs of older adults, their user experience significantly improved after using the application. To explore the speech behavior of older adults when visiting Facebook, Chou et al. (88) proposed the design of social media platforms that are easy for them to use and the design factors that are suitable for them by identifying the user environment suitable for older adults, including web page accessibility, interface design, etc. Among the factors influencing physiological accessibility are readability, visual recognition, and complexity of text input. Also, the results of semi-structured interviews showed that older Chinese users often had problems and barriers like farsightedness, myopia on top of farsightedness, memory bias, and a lower ability to understand. If adequately designed, older adults can effectively use mobile devices or apps (89). The graphic features of the smart home social interface, such as images, text, logos, icons, color blocks, and some buttons, as well as the information architecture features, such as interface layout, hierarchical structure, navigation, and search, will psychologically compensate older users during their use of smart home social media and help them perform online social activities, thus enhancing their emotional experience, subjective well-being, and fewer depressive symptoms (90, 91). Suppose the social interface of smart homes does not meet the physiological and cognitive needs of older adults. In that case, they will make incorrect choices or will be unable to choose from the complex interface and will be unable to find the features they require from the interface environment, making them unable to engage in online social participation. This is also consistent with the research conclusion of Chou et al. (92), who found through a questionnaire study that 79% of older adults over the age of 55 believe that their needs or preferences are not considered in the current web design.

For example, in the author's interview, "The smart home screen is big, and then its graphics are very clear; I like big things; many functions are easy to find; it is all on top of one interface; it is very convenient for me to socialize online"; "I think this line spacing is very wide; it is very convenient for us to chat and entertain; it is also quite easy to watch" (extracted from representative statements of the interviewees).

5.2. Interaction quality influencing factors

Interaction quality, as one of the influencing factors of social compensation, is mainly reflected in the three sub-categories of human-computer interaction, interpersonal interaction, and the intelligence of smart home social media. This is also consistent with the views of the following studies. In terms of human-computer interaction, Wang (93) is based on the human-computer interaction model, and in the process of studying human-computer interaction between older adults and the companion robot, it was found that the factors that affect the use of social media by older adults include custom voice wake-up words, volume adaptation, repetitive prompts, and the intelligence of voice feedback. Wilson (94) found that the stronger the interaction between devices and technology, the stronger the emotional attachment of older adults. The design of devices and technologies should provide a degree of interactivity, whether from social connections or from the device itself. In terms of interpersonal interaction, to test the impact of family online community members on the overall well-being of older adults, Gazit et al. (95) conducted a survey of 427 older adults and a three-level regression analysis. They found that family online community members play an essential role in the lives of older adults. In terms of intelligence, to make the control of household appliances more intelligent, Shah and

Mahmood (96) introduced a smart home automation system using the Internet of Things (IoT) and its low-cost implementation method. From a technical perspective, the paper introduces in detail how to intelligently automate household appliances through software applications integrated with hardware boards, including how the IoT enables devices to communicate, interact, and exchange data through the Internet, as well as how it improves the comfort, convenience, security, and energy efficiency of the home environment. Therefore, if the interaction between older adults and smart home social media can be more natural, such as through voice interaction, and if it is easier to wake up and respond to older adults instantly with more intelligent content, this will psychologically compensate older adults, who will give a high evaluation to the interaction quality of smart home social media and be more comfortable participating in online social. In the semi-structured interviews, the author found that several participants were willing to use the voice interaction function as well as the smart home for interpersonal communication and interaction.

> For example, "My Xiaomi smart-home smart screen sometimes reminds me: it will rain in Qingdao tomorrow; remember to bring an umbrella when you go out. Every morning I say good morning to Xiaomi, and then it will also say, "I'm here, good morning." Then it will say another warm word; it will tell me what month and number of the lunar calendar it is today; how is the weather in Qingdao today? It says very detailed things, and I just feel especially good" (from the representative statements of the interviewees).

## 5.3. Content quality influencing factors

Content quality, as one of the influencing factors of social compensation, is mainly reflected in the three sub-categories of socialization, shareability, and user-generated content of smart home social media, which is also consistent with the views of the following studies. Jung and Sundar investigated the factors that affect the use of Facebook by older adults. Through an online survey of 352 users over the age of 60, they found that there are four main motivations for older adults to use Facebook: social bonding, social bridging, curiosity, and responding to family requests. Further analysis shows that social bonding (establishing connections with ordinary users) is their main motivation for participating in most activities on Facebook, and this view is also supported by Han et al. (97). In addition, research has found that the ability to interact with other people based on messages on Facebook can lead to more use of Facebook by older adults (62). Chou et al. (92) revealed through a questionnaire study that real-time online conversation is one of the most common Internet features used by people over the age of 55. Pera et al. (98) found through interviews with older adults in Italy and the United Kingdom that photo sharing is a powerful behavior that enhances the well-being of older consumers. Therefore, if older adults can better interact with each other in the process of using smart home social media, can share interesting and useful information at any time, and can post content to express themselves and get more people's approval and attention, all of the above can give older adults a certain psychological compensation. They will not be lonely when they age at home, and then they will feel that the quality of content they get from using smart home social media is high, which can help older adults have a good social experience, and subjective well-being (90).

It has to be pointed out that part of the content and information disseminated in social networks can be manipulated by private groups based on personal goals, which can even lead to the widespread dissemination of fake news, leading to social problems. Zakharchenko et al. (99) explored the impact of social network information dissemination from the event of the 2019 Ukrainian presidential election. The election winner successfully obtained 73% of the vote without any ownership of the issue, overcoming any ideological influence, and was successfully elected. The scholar collects and interprets data through content analysis and discourse analysis of social network information in this process. The study found that "filter bubbles," fake news, and negative campaign messages widely existed in the information of the election process; that is, Ukrainian social media users should be responsible for this. It can be seen that the influence of information dissemination in social networks is becoming increasingly significant, even affecting election activities. Research shows that older adults also express concerns about fake news when using social media but are more eager to use it (100). Therefore, while publishing content to express their views, older adults must investigate the source and accuracy of the content and information to prevent the spread of fake news and avoid causing specific erroneous effects. How to distinguish between fake news and fake information among older adults and prevent the spread of fake news is also a question that needs further consideration in future research. In this study, the older adults interviewed by the author generally agreed on whether smart home social media could be used for intergroup interaction and whether the information could be posted and shared immediately.

> For example, "We also organize some activities together, such as some book clubs, calligraphy conferences, singing conferences, etc. I really feel very involved, and I can get some affirmation that I can't leave" (from the representative statements of the interviewees).

5.4. Service quality influencing factors

As one of the influencing factors of social compensation, the quality-of-service factor is mainly reflected in the two sub-categories of social security and empathy in smart home social media, which is also consistent with the conclusions of previous research. First of all, in terms of social security, from the perspective of technical implementation, Mohi Uddin et al. (101) developed a home automation security system using the IoT and AI to ensure that users can access all electronic devices in the home remotely more securely. The system allows users to remotely access homes through Android Apps and control door locks through face recognition to improve the security attributes of the home. This research explores how to improve the security of smart homes from a technical perspective to support users' perceived security, improve the quality of service of smart homes, and bring better experiences to users. From the perspective of older adults, in order to explore whether older adults will accept social media use, Xie et al. (102), through a semi-structured, open-ended discussion of 10 older adults for seven consecutive weeks, found that privacy concerns are the main factors influencing older adults' acceptance of social media use, as well as key perceived barriers. These conclusions are also supported by Zaalen et al. (103). Secondly, in terms of empathy, a study by Wilson (94) found that the more devices and technologies

FIGURE 7
Social compensation system.
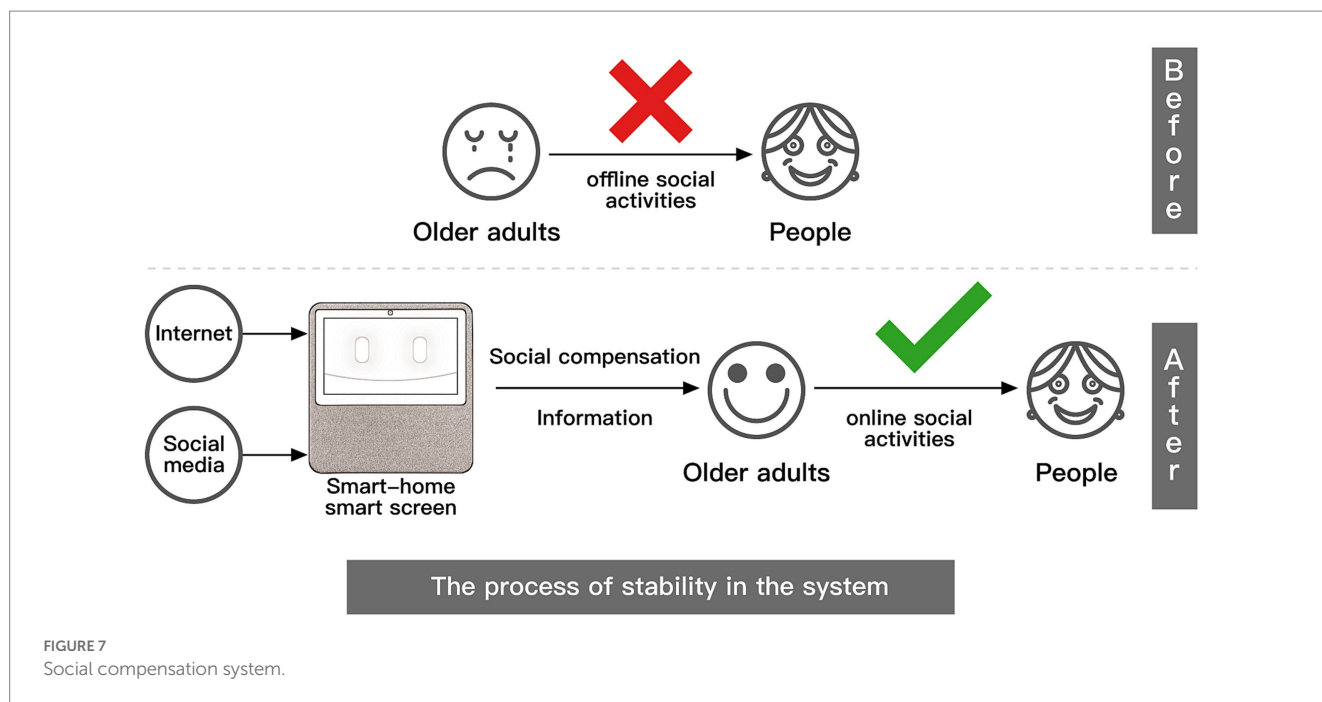
are used, the more emotionally attached users are. Therefore, it can be seen that if older users can feel safe and secure in the process of using smart home social media, such as privacy and payment security, and smart home social media can make them feel companionship as well as personalized services, then it will bring a psychological feeling of compensation to older users, so they will feel the high degree of quality of services they get by using smart home social media, which can help them have a good experience, and subjective well-being (90).

> For example, "Xiaomi is more like my other half in my life; I can't leave it." "I feel that Xiaomi gives me a sense of belonging; I feel that it understands me, and I am connected to it" (from the interviewees' representative statements).

6. Discussions

6.1. Theoretical contributions

6.1.1. Proposing a new construct "social compensation"

From the earliest mass mediums such as newspapers, books, and telephones to the new medium spawned by technological advances such as computers, smartphones, smart homes, and wearable devices carrying social media, people use these media to engage socially, from offline to online. According to the continuity theory (104), it is clear that the degree of social need among older adults does not fade with physiological decline or retirement; their enthusiasm for social participation is strong, and they have the same need to make social connections. Then, in such a dynamic and rapidly changing world, how to overcome the digital divide of the new medium and achieve social participation and, thus, active aging in a family context is the core issue of concern and solution in this study. Based on the terminology of social compensation (20), our study defines social compensation as a

kind of psychological compensation based on using social media in the context of smart homes to compensate the lack of social interaction. The study found that social compensation has three basic characteristics: system, stability, and process. Social compensation is the process of psychological compensation of older adults with insufficient social relations by a new medium equipped with social media in their cognitive system, which eventually leads to a balance, that is, the complementation of social relationships, so that older adults perceive and form positive emotions and eventually accept the process of using it (Figure 7), which also gets supported by Wang and Shi (22). Ultimately, the study proposed factors influencing social compensation between older adults and smart home social media through four core factors: user interface quality, interaction quality, content quality, and service quality.

6.1.2. Revealing the mechanism of social compensation

China's Internet is penetrating the middle and upper age groups, with 25.8% of older Internet users aged 50 and above (105). Older people are increasingly using the Internet, and they are moving their social interactions to social platforms like watching and making short videos (106), video, voice, or text chat, friend circle likes or comments (107), and using WeChat red packets. Although older adults reduce their social participation in offline social networks, they compensate by increasing their social participation in online social networks because personal change is continuous, and there is an overall persistence of lifestyle in social activities and attitudes (108). This creates a foundation for older users to use smart home social media. In the home scenario, older users participate in online social activities through smart home social media, and smart home social media compensate older users socially through social compensation influences as stimuli, which stimulate older users' emotional and cognitive states and satisfy older users' psychological needs, which then stimulate older users' perception. Gradually, the older
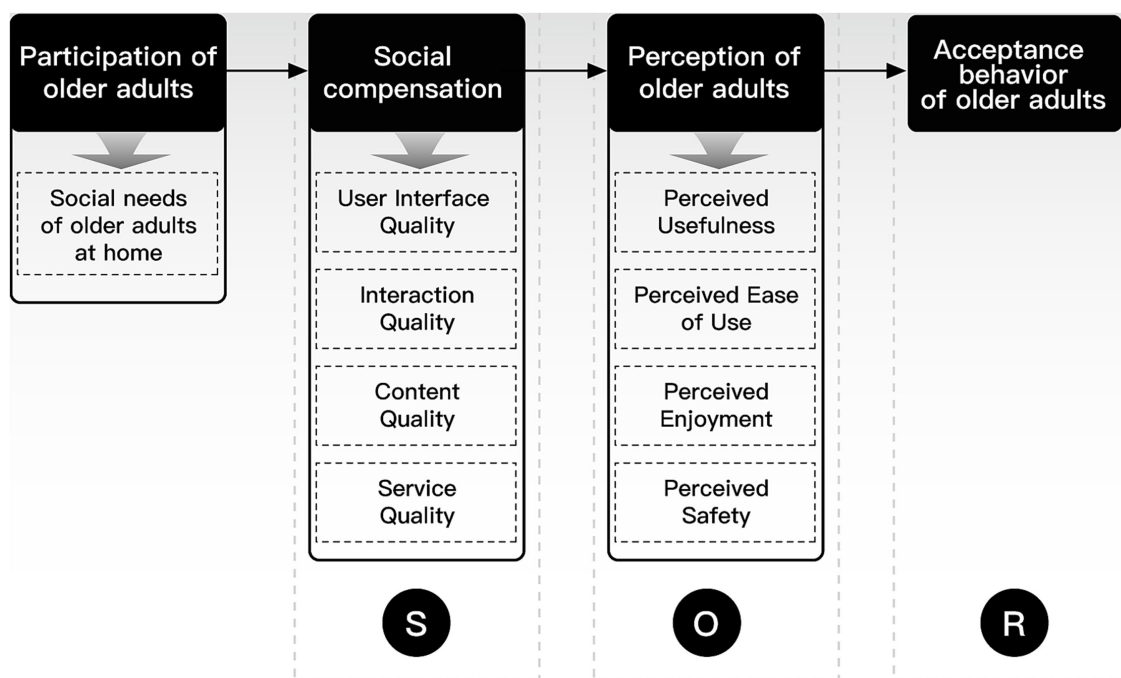
FIGURE 8
The mechanism of social compensation.

users perceive the help brought to them by smart home social media, and gradually, the quantitative change causes qualitative change, which then promotes the adoption and acceptance of smart home social media by the older users.

The mechanism of social compensation is consistent with the stimulus-organism-response (S-O-R) theory (109). In this study, the social needs of homebound older adults and their involvement in using smart home social media created a premise for the establishment of the process of social compensation. The influencing factors of social compensation based on smart home social media serve as external variables (stimuli); older users' perceptions are mediating variables (organisms), and older users' acceptance behaviors are outcome variables (responses; Figure 8).

6.1.3. Discovering the intermediate mechanism from social compensation to the acceptance behavior of older adults

Therefore, social compensation is an attitude model that contains cognitive, affective, and behavioral intentions. The research results show that with the participation of older adults, the social compensation process of smart home social media for older adults is reflected as follows: social compensation → older adults' perception → older adults' acceptance of usage behavior. The final acceptance behavior of older users is the resultant expression of social compensation, and in this process, social compensation has a positive impact on older users' perceptions. Social compensation is a predictive factor of older users' perceptions. User perception refers to users' overall perceptions of social media, and research shows that there are four types of older users' perceptions, including perceived usefulness, perceived ease of use, perceived enjoyment, and perceived safety. Older adults

perceive a positive role through the mediating role of older adults' perception, which can improve the satisfaction of older adults and then manifest in the acceptance of their use in behavior. Perceived usefulness and perceived ease of use are two determinants of older users' acceptance (38, 110) and important perceptual variables in older adults' acceptance of Internet use (48). Perceived usefulness is defined in this paper as the extent to which older users perceive that they can benefit from using social media, i.e., the extent to which they benefit. Perceived ease of use refers to the extent to which older users find social media easy to grasp and use. When considering whether to adopt new technology, older adults are more interested in its products and services' usefulness and ease of use, especially when they are first introduced to the new technology. Due to physiological deterioration and cognitive aging in older adults, they have more barriers to learning to use new technologies, and if older users feel that technology is easier to grasp and use, they will be more confident that the technology is useful to them (41). Perceived enjoyment is an emotional and subjective feeling for older users that refers to the degree of pleasure and joy they feel when using social media. It is also considered an essential variable in older users' acceptance of social media (39, 63, 66). Suppose social media with smart home technology can give seniors a feeling of enjoyment. In that case, it can create a more relaxed and happier atmosphere conducive to seniors' acceptance of smart home social media. Perceived safety refers to how older users perceive their information, property, and personal safety when using social media. Many studies have confirmed that perceived safety affects older users' acceptance of social media (57, 60, 64). The higher the perceived safety, the higher the acceptance of social media by older users. If social media with smart home technology can give seniors a sense of

security, it is more favorable for seniors' acceptance of social media in smart homes. Therefore, older users' perceptions positively impact older adults' acceptance of using smart home social media, and it is a predictive factor of older users' acceptance behavior.

6.2. Practical implications

Building healthy and stable social relationships is a key task for people (111). The social compensation factors and mechanisms of smart home social media proposed in this study can help older adults better socialize at home. First, excellent user interface quality can distinguish social software; thus, managers and developers should consider how to design the graphic features and information architecture of smart home social interfaces based on the specific physiological and psychological decline degree of older adults in order to provide better social compensation to older adults and make them more convenient for online social participation; secondly, based on the main category of interaction quality, a more natural voice interaction mode should be designed according to the human-computer communication mode and habits of older adults, so that older adults can also enjoy a more convenient and responsive interactive service experience. Therefore, managers and developers should strengthen the intelligent design and manage the construction of voice interaction; in addition, managers and developers should use the advantage of the large screen in the smart home social software to design specific community groups and other functions to help older adults show themselves and express their emotions more conveniently, and at the same time, design according to their specific needs so that they can share and pass information to others in the group more conveniently, helping them to get attention more easily, eliminate loneliness, and increase their social participation and interaction. Lastly, from the point of view of service quality, managers and developers should give older users more care and support through specific service elements. This will help older users improve their social experiences, allowing them to interact at home and aging healthily.

6.3. Research limitations

Based on the smart home technology level, this study extracted the social compensatory influencing factors and mechanisms through qualitative research on the use of social media by older adults who age at home, which has a high theoretical innovation value. At the same time, this study has some limitations, such as the fact that it only investigates factors and mechanisms at the technical device level and does not investigate factors that influence the social compensation of older adults from broader dimensions, such as the user level and the environment level. Therefore, future research could explore more social compensation influencing mechanisms at the level of older users and the environment.

7. Conclusion

In general, this study takes the Chinese older adults as the target group, takes the theory of social compensation as the starting point,

and takes the smart home smart screen equipped with local Chinese social media as the research object. The research method adopts the procedural grounded theory, and the interview data are refined and analyzed. On this basis, this paper explores the influencing factors and mechanisms of social compensation for older adults based on smart home social media. Therefore, it can be said that this paper provides theoretical guidance for the future research and development of smart home social media, and has high theoretical and practical value.

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

All respondents in this study have signed the user-informed consent form.

Author contributions

KM: conceptual proposal, development framework, and writing of original manuscripts. MG: coding process, including data extraction, organization, and analysis, edit the manuscript. FG: review and polish manuscripts. RH: project management, resource integration, and manuscript guidance. 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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Community engagement and loneliness in older adults in China: mediation effects of social support in the wake of COVID-19

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Introduction: Loneliness is a key indicator of well-being in older adults. Drawing from the ecological model of aging, the active aging perspective, and the convoy model of social relations, this study investigates the extent community engagement influences loneliness and whether the relationship is mediated by social support during the COVID-19 pandemic.

Methods: Data was collected from 1,067 retired older adults in a cross-sectional design in Chengdu, China in 2022. Structural equation modeling was conducted to examine the direct and indirect effects of community engagement on loneliness through the hypothesized mediator of social support.

Results: The results show community engagement was positively associated with social support ($\beta = 0.26$, $p < 0.001$) and social support was negatively related to loneliness ($\beta = -0.41$, $p < 0.001$). Social support fully mediated the relationship between community engagement and loneliness. Additionally, community engagement had an indirect effect on loneliness via social support ($\beta = -0.11$, $p < 0.001$).

Discussion: The findings from the moderation analysis suggests community engagement and social support are likely to have large effects on loneliness for older adults over the age of 70 and who have low educational attainment. The findings suggest community engagement could be an important factor for improving social support and reducing loneliness amongst retired, older adults in China, especially in the wake of the COVID-19 pandemic where millions of individuals were isolated for extended periods of time.

KEYWORDS

community engagement, loneliness, older adults, social support, COVID-19

Introduction

Loneliness is a state of mind characterized by the perception of being alone and a discrepancy between desired and actual social relationships, regardless of the amount of social contact that an individual experiences (1). Loneliness has shown to be one of the key indicators of wellbeing in older adults. Empirical evidence has also shown that the experience of loneliness is related to poor health outcomes among older adults and can lead to conditions such as cognitive impairment, poor physical health, higher stress, suicidal ideation, and even depression (2–8). Moreover, approximately 16% to 30% of older adults report feeling lonely (9–12).

Loneliness has become a major concern in the medical field because of the detrimental outcomes it can have, and these concerns have only become exasperated in the wake

of the COVID-19 pandemic (13). At the height of the COVID-19 pandemic, billions of individuals worldwide were forced to quarantine, stay-at-home, and isolate from their social networks and community to prevent the spread of the disease (7, 14). Given older adults tend to have more vulnerable health conditions, millions of older adults, particularly those who live in retirement homes or nursing homes, were forced into total separation from their families, communities, and even fellow residents (13, 15). This separation and isolation generated changes to loneliness for older adults regardless of gender and whether they live alone or with someone else (13). Because of its harmful impact on health and wellbeing, loneliness amongst older adults warrants rigorous examination to better understand how its effects could be mitigated during the pandemic. Such insights are crucial for improving our preparedness for future pandemics or catastrophic events.

Studies have also found the extent of loneliness in older adults varies by personal factors such as gender, stage of life, employment status, and health status, as well as environmental factors, such as number of people an individual lives with (3, 9, 10, 12, 16). For example, Srivastava et al. (10) found that retired individuals in India exhibited higher levels of loneliness (18.7%) than did working older adults (13.5%). Dong and Chen (16) found Chinese women had a higher rate of loneliness (28.3%) than older men (23.3%; $p <$ 0.001). Additionally, Gierveld et al. (17) found age, marital status, and perceived lower health status (i.e., not as healthy as I could be) all are associated with higher levels of loneliness.

Regarding environmental influences, various factors such as family functioning, social networks, support systems, a sense of community, and geographic location have all been identified as protective factors against loneliness in older adults (10, 12, 18). The more social networks, emotional and physical support (10, 11, 18), familial interaction, and sense of coherence (6, 18), a person has, the lower the level of reported loneliness. Moreover, where a person chooses to live can also impact their perceived loneliness. For example, living in a rural area has a higher likelihood of loneliness than living in an urban area (10, 12). Additionally, the number of people within a household can also make a difference in loneliness (7). Earlier research shows people living alone reported higher levels of loneliness than do individuals living with at least one other person (13, 19).

Despite how significantly loneliness can impact health outcomes, most of the existing research on loneliness has been focused on the Western context, and less on community engagement and the mechanism between community engagement and loneliness (17, 19). The COVID-19 pandemic has also presented significant obstacles for older adults, including mental health difficulties and limitations in community involvement (7, 14). Given this, our study focuses specifically on the extent community engagement influences loneliness and whether the mechanism is mediated by social support amongst retired, older adults in Chengdu, China during the pandemic. Gaining insights into the interplay of these factors can assist policymakers, social workers, and administrators in senior care to improve the effectiveness of current active aging resources, support systems, and programs across China. The study's findings can also shed light on community engagement and loneliness amid the pandemic, thereby offering implications for addressing new surges of COVID-19 or potential future pandemics.

Community engagement

Community engagement or participation refers the ways individuals are involved within their communities across various life domains, such as domestically, interpersonally, civically, and socially (20–22). By participating in community activities, individuals are provided with opportunities to establish connections and foster emotional support. Consequently, increased community engagement contributes to higher levels of connectedness and social support, which are associated with reduced feelings of loneliness and decreased psychological distress (23–28). That is, social support could serve as a mediator between community engagement and loneliness. For example, O'Mara-Eves et al. (20) conducted a meta-analysis of over 100 studies and found community engagement had a strong effect on social support (effect size=0.44) and self-efficacy (effect size=0.41). Additionally, Schwartz and Gronemann (26) found individuals with active participation in their communities had reduced levels loneliness (beta=-0.57).

Furthermore, in the context of older adults residing in China, the concept of community is frequently intertwined with familial support and connection. Research has demonstrated that these familial relationships play a crucial role in mitigating loneliness, particularly among older adults (15, 29). However, numerous facets of that cultural landscape have undergone transformations since the onset of the COVID-19 pandemic due to quarantine measures. These restrictions have impeded older adults from engaging with their communities and being in the company of their families and friends (14, 30). For example, during the height of the pandemic, the Chinese government implemented the zero-COVID strategy, which entailed imposing stringent lockdown measures. These measures effectively forbade residents from leaving their districts and imposed limitations on social and physical interactions. Individuals, including older, vulnerable adults, were forced to quarantine, stay-at-home, and isolate from their social networks and community to prevent the spread of the disease (14, 15, 30, 31). This separation and isolation generated changes to loneliness for older adults regardless of gender and whether they live alone or with someone else (7, 13).

As China attempted to gradually return to normal, it loosened the zero-COVID strategy by reducing the quarantine period and by allowing people to engage with normal business and community activities if zero COVID cases were reported in the district (32). For instance, in Chengdu, residents residing in low-risk areas were able to participate in regular activities, including community engagements like community reading and singing clubs. Notably, the city underwent a complete lockdown only once for a duration of 2 weeks in September of the year 2022 (33). Thus, it is important to examine the extent of community engagement on social support and loneliness during the pandemic given these changes.

Social support

Social support is the perceived emotional and instrumental support individuals receive from others, including their family members, significant others, community members, and co-workers

(24, 34, 35). Social support is associated with high levels of wellbeing and low levels of loneliness (36–39) because it enables positive self-esteem, companionship, and intimacy with others (40). Perceived social support can also impact an older adult's aging process and how he or she is able to transition to retirement or old age. For example, older adults who have poor or limited social supports tend to have negative attitudes toward aging which in turn can generate loneliness and depression (40). Kafetsios et al. (38) found perceived social support is negatively associated with loneliness ($r = -0.53$) for older adults in Greece. Kearns et al. (39) found the absence of emotional support (OR 1.68) and the lack of practical support (OR 1.54) were positively related to the extent of loneliness in the UK. Meanwhile, Chung and Kim (36) found social support was negatively related to loneliness (beta $= -0.19$) in Korea. Finally, Zhao and Wu conducted a study utilizing data from the China Health and Retirement Longitudinal Survey spanning the years 2013, 2015, and 2018. Their findings revealed that social support played a mediating role in the relationship between social participation and loneliness among older adults in China.

Retired, older Chinese adults have traditionally relied on their children or family members for social and community support (13, 15, 41). For many Chinese adults, it is of typical custom to live with their children through old age. However, due to China's one child policy, modernization of major cities, and changes in migration patterns for job opportunities, many retired, older adults are left living alone in rural areas without any familial social supports in place (41). Consequently approximately 30 million older adults live alone and this number is expected to near double by 2050 (42). Thus, retired, older adults can no longer only rely on their families for their social support and care (41). Instead, this support needs to come from the local community (37, 43).

In short, empirical data indicates that community engagement plays a crucial role in fostering social support and reducing levels of loneliness among older adults. It is worth noting that social support may act as a mediator between community engagement and loneliness. However, taking into account the influence of pandemic-related restrictions on community engagement (7, 13, 14), along with the significant and rapidly growing older-adult population in China (44), it is plausible that the changing ecological environment for older adults during the pandemic may exert dynamic effects on their levels of involvement in community engagement and social support. These changes, in turn, can affect their experiences of loneliness, aligning with the propositions of the ecological model of aging (45, 46). Thus, it is imperative to investigate the effects of community engagement on loneliness and the role played by social support in this relationship, particularly during the pandemic.

Conceptual model and hypotheses

The ecological model of aging postulates the dynamic process of biological, behavioral, and environmental factors affects age progression (45–47). Moreover, this model indicates certain conditions and environmental factors can either promote or inhibit social connection and inclusiveness (48–50). Some of these conditions and factors include level of bodily functioning,

confidence, self-esteem, family/friend relationships, proximity to social network, financial security, self-advocacy, access to community groups, and even access to politics (50). Of these factors, community engagement plays a significant role because it encourages individuals to actively participate socially, economically, culturally, and spiritually within their communities (27, 50). Ultimately, as the active aging perspective suggests, adequate community engagement can improve retired, older adults' quality of life (27), lower levels of loneliness, and even improved mental health and general wellbeing (23, 25, 27).

Additionally, according to the convoy model of social relations, relationships form an evolving social network that surrounds an individual and significantly influences their health and wellbeing throughout their lifespan (51, 52). This model emphasizes the reciprocal nature of support exchange between members of the social network, highlighting the importance of both giving and receiving support within the convoy. Moreover, the intrinsic significance of close social support relationships becomes particularly vital in later life due to the aging process, which diminishes the physical and mental capabilities of individuals to effectively cope with life's challenges in solitude (43, 52).

Based on the ecological model of aging, the active aging perspective, and the convoy model of social relations, this study aims to (1) examine the effects community engagement has on loneliness and to (2) investigate whether the effect is mediated by social support amongst retired, older adults in China. Additionally, we further examine whether these relationships are affected by personal factors such as gender, age, education, and living status. The conceptual model is illustrated in Figure 1. Specifically, we hypothesize:

(1) Community engagement is positively associated with social support.
(2) Social support is negatively associated with loneliness.
(3) Community engagement has a significant, indirect effect on loneliness via social support.
(4) The relationships amongst community engagement, social support, and loneliness were affected by personal factors such as gender, age, education, and living status.

Though current scholarship has shown community engagement has effects on loneliness via social support, there is little knowledge on social support's mediating effects between community engagement and loneliness, and how these two variables are influenced by personal factors amongst retired, older adults in China, especially in the wake of COVID-19. The findings of this study may contribute to the understanding of how community engagement affects loneliness through social support in a rapidly developing retired population and can shed light on potential policy and practices that may improve the outcomes of this population.

Methods
Data and sample

Our data collection was centralized to Chengdu, China retirement groups. We utilized a convenience sampling method

FIGURE 1
Conceptual model of community engagement, social support, and loneliness.
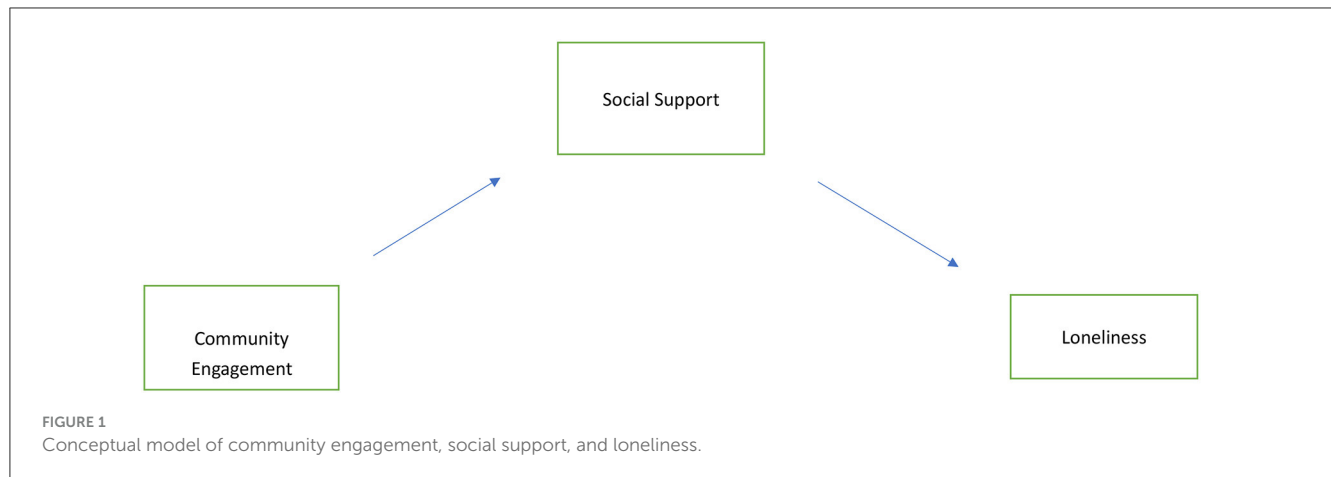
to reach 1,167 seniors at different senior centers around the city from April 27 to June 27, 2022. Specifically, we chose senior centers based in five communities with high proportions of retired, older adults. These five communities were in low-risk COVID-19 zones, so residents were allowed to engage in normal business and community activities during the time of the survey. The inclusion criteria of the sampling process contained individuals who (1) resided within the five communities selected for this research, (2) were 50 years old or older, and (3) were retired at the time of the survey. We excluded older adults who never employed or were working at the time of the survey. Each community had around 250 retirees. Using the help of social workers and street-level social agencies, we distributed 1,167 questionnaires and received 1,085 completed back. However, 18 of the questionnaires were missing key variable data, so we removed them from the analysis. Thus, our total sample was 1,067 retired, older adults. Each adult was paid 3 RMB (0.5 USD) for their participation. Additionally, all participants were notified of their voluntary participation and given proper informed consent protocol prior to beginning the questionnaire. This research protocol was approved by the research review committee at the Research Institute of Social Development in the Southwestern University of Finance and Economics in China.

Measures

Loneliness

We measured loneliness, the outcome variable, using the 8-item UCLA loneliness scale ("ULS-8") (53). The ULS-8′s psychometric soundness, reliability, and validity have been previously verified in other studies performed worldwide (6, 31, 54, 55). Participants were asked to respond to different prompts such as "I lack companionship" and "There is no one I can turn to" and then rate how often they felt that way from 1 ("never") to 4 ("always"). During our analysis, we reversed positive questions so higher scores indicated greater loneliness. Each participant was then given a total score ranging from 8 to 32. The Cronbach's alpha was 0.79.

Community engagement

Next, we measured community engagement using the 8-item community engagement scale, which has demonstrated acceptable reliability and validity within studies based on Chinese populations (56). Respondents reported the frequency they engaged in the following activities within their community: "meet and greet neighbors", "ask neighbors for help", "helping neighbors"; "discuss problems or issues in the neighborhood with neighbors", "participate in community activities", "report problems in the community to the management", "participate in community meetings", and "participate in community organizations". The engagement formats contain both in-person and online approaches. Possible responses range from 1 ("never") to 4 ("frequently"). Each participant's scores were then averaged. Possible scores ranged from 1 to 4. Here, the Cronbach's alpha value was 0.86.

Social support

Third, we measured social support using the 12-item perceived social support scale, ("PSSS") (35) which has shown strong reliability and validity within studies based on Chinese populations (57–59). The PSSS assesses how participants perceive their social supports from family, friends, and others. For example, participants were asked to rate how strongly they agree from 1 ("very strongly disagree") to 7 ("very strongly agree") to statements like "I can count on my friends when things go wrong." and "There is a special person in my life who cares about my feelings." During our data analysis, we averaged the participants' answers and gave everyone a score ranging from 1 to 7. The PSSS had a Cronbach's alpha score of 0.95.

Analytical approach

For all analyses we used version 16.0 of STATA statistical software. First, we performed a descriptive analysis of the key variables to understand the sample's characteristics. Second, we performed a Pearson's correlation analysis to investigate correlations amongst the variables. Third, we conducted a structural equation modeling (SEM) analysis to simultaneously

	Mean (S.D.)
Age	65.9 (9.2)
50–59 [%]	25.2
60–69 [%]	42.7
70 and above	32.1
Gender (Female) [%]	56.0
Education	
Below high school [%]	22.1
High school [%]	33.5
Above high school [%]	44.4
Living Status	
Alone [%]	7.0
With another person [%]	38.6
With more than one person [%]	54.4
Community Engagement [1–4]	2.3 (0.6)
Social Support [1–7]	4.9 (1.1)
Loneliness [8–32]	15.8 (4.2)

N = 1,067.

	Community engagement	Social support	Loneliness
All	2.29 (0.59)	4.91 (1.05)	15.78 (4.16)
Age			
50–59	2.22 (0.60)	4.85 (1.12)	16.27 (4.23)
60–69	2.29 (0.54)	4.95 (0.97)	15.38 (4.09)
70 and above	2.35 (0.64)	4.89 (1.12)	15.93 (4.15)
F-test	10.6 **	0.9	4.2 *
Gender			
Male	2.33 (0.59)	4.91 (1.00)	15.75 (4.02)
Female	2.26 (0.58)	4.90 (1.11)	15.82 (4.27)
F-test	3.3	0.1	0.1
Education			
Below high school	2.28 (0.53)	4.66 (1.13)	16.71 (3.82)
High school	2.26 (0.61)	4.93 (1.11)	15.99 (4.14)
Above high school	2.32 (0.60)	5.01 (0.96)	15.16 (4.23)
F-test	1.2	9.1 ***	11.8 ***
Living Status			
Alone	2.29 (0.56)	4.88 (1.09)	16.83 (3.89)
With another person	2.30 (0.58)	4.89 (1.08)	15.63 (4.22)
With more than one person	2.29 (0.60)	4.91 (1.03)	15.76 (4.13)
F-test	0.1	0.1	2.7

N = 1,067. Numbers in parentheses show standard errors. **$p < 0.01$, ***$p < 0.001$.

examine the direct and indirect effects community engagement had on loneliness through the hypothesized mediator of social support. The SEM analysis was the preferred method because it allows for the simultaneous direct and indirect examinations of the mediating variable. The maximum likelihood (ML) estimation was used in SEM. We assessed the model-to-data fit using several fit indices, such as Chi-square statistics, Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Values of Chi-square statistics >0.0.05, CFI> 0.95, RMSEA values <0.08, and SRMR<0.08, all indicated good model-to-date fit. Finally, we further conducted the multi-group SEM analysis using personal factors, such as gender, age, education, and living status, to test the moderation effects (60). The multiple-group analyses provide the opportunity to investigate whether the estimated pathways within the model exhibit variations among different subgroups. These analyses involve the generation and comparison of subgroup estimates between an unconstrained model and a constrained model. In the unconstrained model, all estimated paths are allowed to vary across subgroups, while in the constrained model, all paths within the model are held equal across the subgroups. To assess the fit of these models to the data, we employ the likelihood ratio test. A significant test result indicates that the unconstrained model offers a superior fit to the data, suggesting that the pathways within the models differ across subgroups.

Results

Table 1 lists the characteristics of the final sample. The average age of the sample was 65.9 years old (S.D. = 9.2), but a majority were between the ages of 60 and 69 (42.7%). Nearly one third of the

sample was over 70 years old (32.1%) and one quarter were between ages 50 and 59 (25.2%). Additionally, 56% of the sample identified as female. About 44.4% of the sample reported having a high school education or higher, while 33.5% and 22.1% of them had only high school or below high school education, respectively. Finally, about 7% of the sample reported they lived alone, while 38.6% reported they lived with only one other person. However, most of the sample lived with more than 1 person (54.4%). The sample had an average community engagement score of 2.3. Perceived social support had a mean score of 4.9. Overall, the sample reported an average loneliness score of 15.8. Moreover, the descriptive statistics suggest on average the sample reported modest levels of community engagement, social support, and loneliness. The levels of community engagement, social support, and loneliness were varied by demographics as shown on Table 2.

Table 3 presents the findings from the correlation analysis on the key variables. The findings were consistent with our hypotheses. First, community engagement had a positive correlation with perceived social support (r=0.26, $p < 0.001$) and a negative correlation with loneliness ($r = -0.13, p < 0.001$). Moreover, social support had a negative correlation with loneliness ($r = -0.31, p < 0.01$).

The standardized estimates of the SEM model are listed in Figure 2. The model fit statistics showed the proposed model

fit adequately into the data: $\chi 2$ (1) $= 0.67$, $p > 0.05$, CFI $= 1.00$, RMSEA $= 0.00$, SRMR $= 0.01$. Additionally, community engagement had a positive effect on social support ($\beta = 0.26$, $p < 0.001$). Together, these results confirm Hypotheses 1. Consistent with Hypothesis 2, social support had a direct and negative effect on loneliness ($\beta = -0.41$, $p < 0.001$). The SEM analysis yielded results indicating that social support served as a complete mediator between community engagement and loneliness. This was evidenced by the satisfactory fit of the conceptual model, and it was found that community engagement exerted a significant indirect influence on loneliness through its effect on social support ($\beta = -0.11$, $p < 0.001$). These findings are consistent with Hypotheses 3.

The moderation analysis results are listed in Table 4. The results of the likelihood-ratio tests showed the estimates of community engagement on social support and loneliness were significantly moderated by age, education, and living status. The effects of community engagement on social support tend to be larger for adults who were over the age of 70, and between the ages of 50 and 59, with below high school level education, and who lived with more than 1 person. In contrast, the effects of community engagement were small for older adults aged between 60 and 69, with a high school education, and who lived alone. Social support had a larger effect on loneliness for older adults who were 60 years old and older, with an above high school level education, and who lived with another person. Overall, the indirect effects of community engagement on loneliness via social support tends to be large for adults over the age of 70, with a below high school level education, and who lived with 1 or more person.

Discussion

The retired, older adults in this study, on average, reported moderate levels of loneliness. The average score of loneliness here was 15.9, which is lower than retirees report in Nigeria [20.3; (61)], but higher than what senior citizens report in the Philippines [7.2; (62)], higher than senior citizens in rural parts of China [11.1; (63)], higher than migrant older adults in China, [12.8; (31)], and higher than community older adults in Singapore [14.4; (64)]. These comparisons suggest that the degree of loneliness experienced by retired, older adults in Chengdu, China falls within the spectrum of loneliness observed in different studies focusing on older adult populations, both internationally and domestically.

The sample also reported modest levels of community engagement and social support. Although there is a positive inclination toward observing older adults engaging in community activities and receiving social support during the pandemic, evaluating the actual effects of the pandemic on the extent of community engagement and social support presents difficulties. This is primarily because the available data is derived from a one-time cross-sectional survey, which limits the ability to track longitudinal changes and draw definitive conclusions about the impact of the pandemic on these factors. Additionally, these descriptive findings are also limited to the experience of older, retired adults in Chendgu, China and may not be generalizable to individuals in other regions of China. Future research should expand upon our findings to investigate the extents of community engagement, social support, and loneliness among retired, older adults in either other Chinese cities or on a different time point to assess the effects of region and time on the statistics.

Next, the SEM analysis results showed community engagement had a modest effect on increasing social support and that social support had a strong effect on reducing loneliness during the pandemic. The findings indicate that social support plays a crucial mediating role between community engagement and loneliness among retired older adults in China during the pandemic. Moreover, these findings are consistent with the ecological model of aging, the active aging perspective, and the convoy model of social relations, and suggest that community engagement has the potential to improve quality of life by increasing social support and reducing loneliness (15, 23, 25, 43), and that social support, as a

TABLE 3 Correlation analysis of key variables.

	1	2	3
1. Community engagement	—		
2. Social support	0.26***	—	
3. Loneliness	−0.13***	−0.41**	—

$N = 1,067$. ** $p < 0.01$, *** $p < 0.001$.

FIGURE 2
Standardized estimates of community engagement, social support, and loneliness. *** $p < 0.001$.
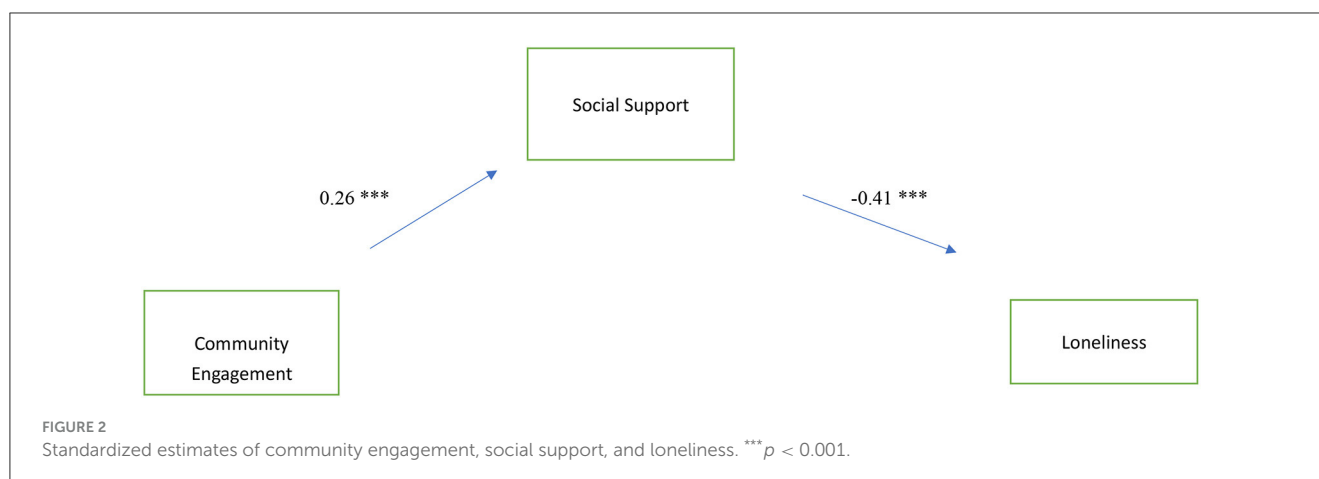
TABLE 4 Direct and indirect effects of community engagement and social support on loneliness.

Independent variable	Dependent variable	Direct effect	Indirect effect
All sample			
Community engagement	Social support	0.26***	—
Community engagement	Loneliness	—	−0.11***
Social support	Loneliness	−0.41***	
Gender			
Male			
Community engagement	Social support	0.27***	—
Community engagement	Loneliness	—	−0.11***
Social support	Loneliness	−0.42***	
Female			
Community engagement	Social support	0.26***	—
Community engagement	Loneliness	—	−0.10***
Social support	Loneliness	−0.40***	
Likelihood-ratio test		8.45	
Age			
50–59			
Community engagement	Social support	0.30***	—
Community engagement	Loneliness	—	−0.10***
Social support	Loneliness	−0.33***	
60–69			
Community engagement	Social support	0.17***	—
Community engagement	Loneliness	—	−0.08***
Social support	Loneliness	−0.47***	
≥70			
Community engagement	Social support	0.33***	—
Community engagement	Loneliness	—	−0.14***
Social support	Loneliness	−0.41***	
Likelihood-ratio test		29.5**	
Education			
<High school			
Community engagement	Social support	0.41***	—
Community engagement	Loneliness	—	−0.15***
Social support	Loneliness	−0.36***	
High school			
Community engagement	Social Support	0.17***	—
Community engagement	Loneliness	—	−0.07**
Social support	Loneliness	−0.38***	
> High school			
Community engagement	Social support	0.27***	—
Community engagement	Loneliness	—	−0.12***
Social support	Loneliness	−0.44***	

(Continued)

TABLE 4 (Continued)

Independent variable	Dependent variable	Direct effect	Indirect effect
Likelihood-ratio test		66.2***	
Living status			
Alone			
Community engagement	Social support	0.17	—
Community engagement	Loneliness	—	−0.04
Social support	Loneliness	−0.24*	
With another person			
Community engagement	Social support	0.22***	—
Community engagement	Loneliness	—	−0.11***
Social support	Loneliness	−0.51***	
More than 1 person			
Community engagement	Social support	0.31***	—
Community engagement	Loneliness	—	−0.11***
Social support	Loneliness	−0.36***	
Likelihood-ratio test		22.4*	

N = 1,067. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

mediator, effectively reduces the extent of loneliness even during the pandemic (37, 43).

The findings of this study have several practical implications. First, given community engagement is significantly associated with social support and loneliness of retired, older Chinese adults, it is imperative for retiree programs to implement interventions and services that promote community engagement. These efforts will aid retired older adults in enhancing their social support networks and subsequently mitigating feelings of loneliness, especially in the face of new waves of COVID-19 or potential future pandemics. Although the Chinese government has made efforts to promote community engagement amongst older adults in recent years (29, 65) more efforts need to be taken to continue to improve community connections and residents' wellbeing given the findings of this study over the pandemic period. Doing so can increase health incomes for older adults in a major way when they face life challenges such as the global pandemic or other crises.

Second, given social support strongly effects loneliness, other interventions and services that are successful at improving social support should be implemented. For example, studies have shown social connection and network interventions can improve social support and reduce loneliness in older adults (66, 67). In addition, there is evidence that information and communication technology can improve life and social support for older adults (31, 68, 69). Consequently, social connection and advancing technology hold promises in improving social support amongst retired, older adults.

Third, the moderation analysis findings suggest community engagement and social support programs may work effectively for some groups, while have limited effects on others. Specifically, community engagement is likely to have large effects on social support for vulnerable groups such as older adults aged 70 and above (beta = 0.33) and with a below high school level education (beta=0.41). Thus, government agencies should prioritize targeting these groups for interventions and services to improve their perceived loneliness during the pandemic or other crises.

However, for older adults who live alone, community engagement seems have a small effect on social support and that social support also has limited effects on loneliness. These findings suggest community engagement might not strongly related to social support and loneliness of older adults living alone. The findings are in line with previous research on community engagement, social support, and loneliness for older adults living alone (19, 70). For example, Schafer et al. (19) found for Americans and Europeans, having larger, diverse community networks outside the home reduces the loneliness of living alone, but even still with extensive community connections, individuals who live alone report higher levels of loneliness than those who live with someone else. Thus, the Chinese government and various social work agencies may want to seek other approaches such as technology or peer-based interventions to increase social support and reduce the extent of loneliness for older adults who live alone (68, 71). For example, Czaja et al. utilized a randomized field trial and found that the communication technology intervention was significantly increased social support and reduced loneliness for older adults living alone.

This study also has several limitations. First, the study used a cross-sectional design, which prevented us from inferring any causal relations among community engagement, social support, and loneliness. Future studies should consider implementing a longitudinal design to account for temporal sequencing and to better understand the causal relations among these variables. In particular, the design should include both pandemic and post-pandemic period to comprehend the effects of the pandemic on these variables. Second, the data relied on self-reports of retired, older adults in Chengdu, China. Though self-reporting is a common method for data collection, it might be associated with

self-reporting biases that can affect the estimates of the results. Third, the data collection occurred in one city, Chengdu, so our findings may not be generalizable to the larger population of retired, older adults in China. A future study could expand upon our findings by examining how geographic differences in China (e.g., rural vs. urban) might affect the mediational pathway between community engagement and loneliness through social support. Also, the sample is limited to retired, older adults, so the findings may not be generalizable to older adults who never had a job or who were working part time after retirement.

Fourth, the results demonstrate the effects of community engagement on social support tend to be greater for older adults over the age of 70 that live with at least one other person. However, our study primarily consisted of individuals under the age of 70 (the average age of the group was 65.9 with a standard deviation of 9.2). Thus, future research may want to focus on the experience of individuals who are living with at least one other person and are over the age of 70 to understand specifically what aspects of community engagement and social support associate with their loneliness most. Moreover, individuals who retire are at higher risk for developing depression and other mental disorders because of the major social changes and financial challenges retirement can bring (72). Thus, newly retired individuals who are still going through this major life transition, may have skewed perceptions of their loneliness and social connection with others. Given our sample was particularly young and just about at the age for retirement in China, participants may have skewed answers about their perceived loneliness because they are still adjusting to newfound life and social dynamics. Future research may consider assessing the perceptions of retirees who have had many years to adjust to their realities and support networks.

Fifth, we found community engagement has limited effect on social support ($\beta = 0.17$) and social support has no significant effect on loneliness for old adults living alone. This could mean that community engagement during the pandemic appears to have small effect on social support and loneliness among older adults living alone. However, the sample size for this group was relatively modest, comprising only 7% of the sample ($n = 75$). Consequently, additional research is required to gain a comprehensive understanding of how community engagement affects social support and loneliness among older adults living alone, using larger and representative samples.

Finally, the COVID-19 pandemic changed the way people are able to interact with their community and social support systems. For example, research shows more older adults in China are acquiring access to technology, such as the internet and smartphones, to facilitate communication and connection (69, 73, 74). This study does not incorporate how technology influences loneliness, community engagement, and social support. Future research should explore how these tools can help older adults reduce loneliness and build connection. Moreover, while this study recognizes the impact COVID-19 has had on loneliness amongst older adults in China, the study does not seek to understand how the pandemic changed loneliness. Instead, it merely examines how loneliness is now for older adults in Chengdu, China without comparing it to what loneliness levels may have once been. While there have been some studies on the impact COVID-19 has had on loneliness (13), future studies should continue to explore the long-term effects COVID-19 has had on older adults in Chengdu, China and understand how different interventions may work to improve loneliness, social support, or community.

Conclusion

In a sample of 1,067 retired, older Chengdu, China based adults, there was evidence community engagement influences loneliness, and this relationship is mediated by social support during the COVID-19 pandemic. Moreover, these findings support existing cross-cultural research on community engagement, social support, and loneliness. Community engagement should continue to be used as a mechanism to improve social support and to ultimately reduce loneliness. Loneliness has a powerful effect on individuals and can negatively affect general health and wellbeing of individuals, particularly for retired, older adults, during the pandemic and other life crises. This study calls for interventions and services that promote community engagement and social support for retired, older adults in China. This is incredibly imperative, given the COVID-19 pandemic has isolated many older adults from necessary community and social supports, and continues to have a lasting impact today.

Data availability statement

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

Ethics statement

The studies involving humans were approved by the Research Review Committee, Research Institute of Social Development, Southwestern University of Finance and Economics. 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

XX and CH: conceptualization and resources. XX, CH, SS, and XQ: methodology and software, validation, formal analysis, and writing—original draft preparation. XX, CH, and XQ: investigation and data curation. 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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A study on the impact of health shocks on subjective wellbeing of middle-aged people and older adults—Evidence from China

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Introduction: The health issues that afflict middle-aged people and older individuals are a significant factor that affects their quality of life. It is crucial to investigate the impact of health shocks on the subjective wellbeing of this demographic and the mechanisms that underlie this impact to promote healthy aging.

Methods: This study utilized data from the China Family Panel Study in 2018 and 2020 to analyze the effects of HSs and their categories on the subjective wellbeing of middle-aged people and older individuals using the propensity score matching difference-in-differences method. Additionally, the study explored the mediating role of social participation.

Results: The findings indicate that health shocks, both chronic and acute, diminish the subjective wellbeing of middle-aged people and older adults. Furthermore, these shocks have a more significant negative effect on the subjective wellbeing of individuals aged 60 and above, women in the middle-aged and older demographic, individuals in rural areas who belong to the middle-aged and older age groups, and individuals possessing activities of daily living. The mechanism analysis revealed that health shocks, both chronic and acute, reduce the subjective wellbeing of middle-aged people and older individuals by disrupting partnerships.

Discussion: Lowering the possibility of health shocks, the government should build a strong health management system and improve the health insurance system to enable timely treatment for persons suffering from health shocks. Individuals and families should live healthy lives and engage in social activities to avoid health shocks and improve subjective wellbeing.

1 Introduction

As per the National Bureau of Statistics of the People's Republic of China, by the end of 2022, 14.9% of China's population will be aged 65 and over (1), marking the country's entry into an aging society. Despite the increasing life expectancy in old age, there has been no corresponding improvement in health functioning (2, 3). The aging of the population has significant implications for economic and social development, with the health status and quality of life of older individuals playing a crucial role (4). The risk of disability

and cognitive impairment also increases significantly with age (5, 6). Given this context, promoting healthy aging and enhancing the wellbeing of older individuals has become a pressing concern for both the government and society at large. In 2019, the State Council issued the Opinions on Promoting the Development of Elderly Services, which aims to improve the wellbeing, access, and security of older individuals (7). The international community has also recognized the importance of promoting people's wellbeing, with the United Nations publishing the World Happiness Report annually since 2012 to guide governments and society in focusing on people's happiness. Therefore, studying the factors that influence subjective wellbeing and identifying ways to improve it is crucial for achieving healthy aging and enhancing the quality of life of older individuals (8).

Subjective wellbeing is a crucial psychological indicator of an individual's quality of life, which can be directly influenced by changes in health status (9). The correlation between health status and wellbeing has garnered academic interest, particularly in the context of older individuals. Research suggests that good health can contribute to increased levels of subjective wellbeing in older individuals (10). Conversely, when older individuals experience impaired health, such as reduced perceptual speed or impaired vision and hearing, their subjective wellbeing is also diminished (11, 12). However, it has also been posited that there is no significant effect between the two, and that subjective wellbeing is relatively stable in older individuals with Parkinson's syndrome (13). In the literature, there is little consensus on the association between health and subjective wellbeing in older persons. Furthermore, the mechanisms influencing the association between health shocks and subjective wellbeing have not received much attention in the literature. A person's ability to engage in social activities may be restricted by deteriorating health (14), and social contacts are a crucial source of emotional and supportive resources for people (15). Therefore, further research is needed to ascertain whether a health shock affects an individual's social participation and subsequently influences their subjective wellbeing.

This study aims to objectively measure changes in health among middle-aged people and older adults. By distinguishing between different types of health shocks, examining how they affect the subjective wellbeing of this demographic, and comparing the differences between chronic health shocks and acute health shocks on their subjective wellbeing, we can reveal the pathways through which they experience health shocks and explore strategies to improve their subjective wellbeing. Meanwhile, examining differences in the effects of health shocks on subjective wellbeing across different groups of middle-aged people and older adults not only aids in the identification of potential subgroup effects, but also serves as a foundation for future individualized interventions and policy development. To achieve this, a sample of middle-aged people and older individuals aged 45 and above was selected from the China Family Panel Studies (CFPS) 2018 and 2020 microdata. Firstly, the propensity score matching difference-in-differences (PSM-DID) model was utilized to investigate the impact of health shocks on their subjective wellbeing. Secondly, the mediating effect model was employed to analyze the transmission mechanism between health shocks and subjective wellbeing, and to verify the mediating role of social participation. Finally, this study examines the variability of the impacts of health shocks on subjective wellbeing among groups of varying ages, genders, areas of residence, and activities of daily living (ADL). These assessments aim to give a foundation for decision-making in order to promote the wellbeing of middle-aged people and older adults in the context of aging.

Significant contributions have been made by this study. Firstly, this study differentiates between different forms of health shocks. To assess the variations in the impact of different forms of health shocks, the extended analysis is refined from the dimensions of acute and chronic health shocks. This makes the study's findings more objective and reliable. Secondly, the study has explored the transmission mechanism of health shocks on subjective wellbeing of middle-aged people and older adults based on the social capital theory, providing realistic pathways to enhance their subjective wellbeing and achieve the goal of "active aging". Thirdly, the study included a sample of middle-aged people to determine the impact of health shocks on the subjective wellbeing of middle-aged people. This will enable the government to advance the policy protection gateway and act with middle-aged people to lessen the likelihood of health shocks in old age. Lastly, the research model and analysis methods used in the study have clearly covered the correlation between the target variables, transmission mechanisms, and the effectiveness of current policies, laying the foundation for the establishment of a systematic, multi-level, and effective protection system for the middle-aged and older adults.

2 Literature review

2.1 Measurement of health shocks

Health shocks refer to sudden and unexpected deterioration of health conditions that require medical care and may lead to long-term consequences (16). In studies related to health shocks, scholars have primarily measured them in terms of a single dimension, and the existing literature can be divided into two main categories. One category is the acute measurement of health shocks using subjective indicators. The indicator most frequently used by scholars is self-rated health, where individuals make judgments based on their own health status (17, 18). Poorer health is considered a health shock. Data for this indicator are readily available and contain a large amount of information, but there are obvious limitations. Self-rated health is somewhat subjective, and individuals' standards of good or bad health may change over time, or they may even choose to conceal their true health status in order to conform to social expectations or avoid stigma (19).

Another category measures health shocks using objective indicators. Some scholars in health economics use anthropometric indicators, such as changes in body weight and body mass index (BMI), to measure health shocks (20). Although these indicators can compensate for the lack of subjective self-assessment of health, they can be influenced by other environmental factors such as age, gender and ethnicity (21) and do not fully reflect current health status.

Other scholars represent health shocks by using impairments in the ability to care for oneself in daily life, medical expenditures, length of hospital stay, or time spent inactive due to illness to

represent health shocks (22–24). Although these metrics are less affected by subjective bias, they have limitations. In order to measure health shocks more objectively, some scholars have judged them by the presence or absence of a certain disease (25, 26). However, no distinction is made between types of illnesses, and it is not possible to compare differences in the impact of health shocks caused by different illnesses.

2.2 Health shocks and subjective wellbeing

Subjective wellbeing, a fundamental variable in the economics of happiness, refers to an individual's comprehensive evaluation of their state of life and is a composite reflection of their social functioning and adjustment (27). It has been established that subjective wellbeing can alleviate psychological stress and reduce suicidal ideation (28, 29). Moreover, individuals with a high level of subjective wellbeing tend to live longer, thereby prolonging life to some extent (30). The existing literature on the impact of health on subjective wellbeing focuses on both physical and psychological health.

Individuals in better physical health typically exhibit higher levels of subjective wellbeing (31). In contrast, those with chronic physical illness or severe pain exhibit much lower levels of subjective wellbeing than their physically healthy counterparts (32). It is worth noting that mental health significantly affects the subjective wellbeing of older people (33), even more so than physical health levels (34). Generally, optimistic, positive, and healthy emotions have a positive effect on subjective wellbeing in older people (35), while negative emotions such as anxiety and depression have a negative effect (36). Additionally, health and subjective wellbeing are believed to be causal. Kushlev et al. assessed the association between subjective wellbeing and health behaviors in a broad representative sample of nearly 2.5 million respondents from the USA and found that both life satisfaction and positive affect predicted health behaviors (37). Furrer et al. found that patients with higher subjective wellbeing showed lower pain intensity, and pain intensity was reduced in patients with physical illness or disability by means of enhancing subjective wellbeing, such as positive psychology exercises (38). The worldwide outbreak of the COVID-19 pandemic and the measures taken to prevent and control its spread have had a profound impact on the subjective wellbeing of individuals (9). The research revealed that the COVID-19 pandemic precipitated a substantial decline in outdoor physical endeavors, a surge in the duration of time spent on social media and the internet, a notable reduction in subjective wellbeing, and an escalation in the consumption of fast food (39). During the epidemic, a positive attitude toward risk and death was found to be effective in reducing psychological distress and increasing wellbeing (40).

The timing of life events and the interconnection of persons are emphasized in life course theory (41), and the life course factor has a tremendous impact on an individual's health and wellbeing. The timing element underlines the fact that the identical state changes occur at different times and have different consequences on different people (42). According to research, the subjective wellbeing of older persons varies with age (43, 44). Individuals' beginning disadvantages build over time throughout

their lives, resulting to a tendency for systematic divergence of health condition among individuals (45). Disparities in gender, urban/rural residence, and activities of daily living contribute to these drawbacks.

Regarding gender, there is no definitive consensus regarding the subjective wellbeing disparities between females and males (46, 47). The enduring female disadvantage in terms of adverse emotional states and subjective wellbeing leads to a greater prevalence of negative psychological experiences and a diminished sense of subjective wellbeing for women compared to men (48, 49). However, this discrepancy is also attributed to the equitable sharing of total household income between both genders, resulting in roughly comparable levels of wellbeing for both men and women (50). Regarding place of residence, individuals encounter distinct social expectations and possess varying socioeconomic resources, which form the basis for their ability to cope with physical and psychological stress (51). Due to China's longstanding urban-rural divide, substantial disparities exist in the availability of health resources for middle-aged people and older adults residing in urban and rural areas (52). Consequently, when faced with health shocks, the trajectories of subjective wellbeing are theoretically divergent for these two groups (53, 54). In terms of daily mobility, disability serves as a risk factor for numerous chronic ailments such as obesity, osteoporosis, and cardiovascular disease (55–57), and it is more likely to have a detrimental impact on the mental health of the aged (58).

2.3 The mediating role of social participation

The theoretical mechanism underlying the influence of social participation as a mediating variable in the pathway of health effects on subjective wellbeing encompasses three fundamental facets.

For starters, the hierarchy of needs is an essential prerequisite and cornerstone for social participation and its impact on older people. According to the theoretical framework of requirements theory, once individuals' basic wants are addressed, they naturally desire to meet higher-level needs, resulting in greater satisfaction (59, 60). However, deteriorated health conditions make it difficult to meet physiological and safety needs, preventing the pursuit of higher-level needs (60). Reduced health status is a barrier to social participation, especially in cases of chronic respiratory ailments, physical and cognitive impairments, or psychological dependence, which are more likely to limit individuals' participation in social activities (14, 61–63).

Secondly, social participation in the form of social activities is a significant way for older people to influence their life. According to social capital theory, social capital refers to an individual's acquisition of the collective resources held by a group, encompassing both the quantity and quality of those resources (64). It signifies an individual's capacity to access limited resources through their involvement in a network or within a broader social structure (65). Interpersonal interactions and social networks are regarded as the fundamental constituents of social capital, as proposed by social capital theory. By fostering and nurturing robust social relationships, individuals can gain access to knowledge,

resources, and support, thereby enhancing their quality of life and expanding their opportunities (66). Social participation is a key means of promoting social capital generation. Closer social interactions can give individuals with emotional and social support resources (15). Social interaction has been found to be a mediator of physical activity and to lower frailty, depressive symptoms, and suicide risk in later life (67, 68).

Finally, the ultimate goal and destination of social participation for older persons is active aging. One of the three pillars of achieving positive aging is social participation, which attempts to integrate older persons into society (69). Older persons' social participation can, to some extent, provide economic and emotional exchanges with families, as well as foster peace and wellbeing in intergenerational relationships (70). Social participation is a significant contributor to older persons' mental health (71, 72), and it can effectively limit geriatric social isolation while also increasing geriatric social cohesion (72).

2.4 Literature summary

The relationship between health and the subjective wellbeing of older persons has not consistently been addressed in the literature, and there are still gaps. The following three aspects are mostly where this is seen. The first is the method used to gauge health. Studies already published focus more on the relationship between subjective health and subjective wellbeing than health shocks, and there is a dearth of information on how different health shocks affect people differently. Secondly, on the mechanism of the influence of health shocks on the subjective wellbeing of the older adults is limited. Existing research focuses mostly on the direct impact of changes in health status on the subjective wellbeing of the aged, but there is a dearth of study on the process through which it has an influence. Subjective wellbeing is influenced not only by the individual, but also by the social environment. It is vital to investigate the influence mechanism and identify a way for improving the subjective wellbeing of middle-aged people and older persons. Thirdly, existing research concentrates on the older over the age of 60 and ignores the middle-aged population. Individuals' health status in middle age has a significant impact on their health later in life. Focusing on the trajectory of individual health status and subjective wellbeing in middle age can assist in providing tailored policy protection for the middle-aged group and lowering the likelihood of sickness in old age.

This paper endeavors to address gaps in the current research literature by examining the influence of health shocks on the subjective wellbeing of middle-aged people and older adults. The study focuses on the objective health dimension of health shocks and distinguishes between the varying effects of chronic health shocks and acute health shocks. The underlying hypothesis posits that health shocks, both chronic and acute, will adversely affect the subjective wellbeing of middle-aged people and older adults. As a result of experiencing health shocks, this demographic may experience a reduction in their social participation and overall wellbeing. The ultimate goal is that these findings will aid in the development of strategies aimed at enhancing and promoting active aging.

3 Methodology

3.1 Method

The aim of this study is to examine the impact of health shocks on the subjective wellbeing of middle-aged people and older adults. To address this inquiry, the study employed health shocks as a quasi-natural experiment. The PSM-DID model was utilized to quantify the effect of policy implementation by carefully selecting comparable treatment and comparison groups. For the purpose of this study, the treatment group was composed of middle-aged people and older adults who did not experience either a chronic or an acute health shock in 2018 but encountered either a chronic or an acute health shock in 2020. On the other hand, the control group consisted of middle-aged people and older individuals who did not face any chronic or acute health shocks in both 2018 and 2020. The key concept behind the PSM-DID approach is to reselect the treatment and control group samples to determine, for each middle-aged or older individual who has experienced a health shock, the likelihood of exposure to a health shock in the control group. This approach eliminates selectivity bias and confounding bias that stem from the non-random nature of health shocks. As a result, the rescreened treatment and control groups differ in their levels of subjective wellbeing, except for other characteristic variables (both observable and unobservable variables that remain constant over time, as well as unobservable variables that change synchronously over time), which are as similar as possible, to obtain the net impact of health shocks on subjective wellbeing levels. The corresponding PSM-DID estimators are expressed as follows:

$$\text{ATT}_{\text{PSM-DID}} = \left[Y_1^T - Y_0^T | X, D = 1 \right] - \left[Y_1^C - Y_0^C | X, D = 0 \right]$$

D is a dummy variable for exposure to health shocks (1 is the treatment group, 0 is the control group), T is the treatment group, C is the control group, and Y_0 is the level of subjective wellbeing in the ex-ante group, and Y_1 is the level of wellbeing in the ex-post group. The outcome variables in the PSM-DID approach are no longer cross-sectional data for a particular period, but rather the change in data over a continuous period. Specifically for the questions discussed in this paper, the outcome variable captures the change in subjective wellbeing levels of middle-aged people and older adults between 2018 and 2020.

This study draws on the causal mediation analysis approach constructed by VanderWeele (73) to make causal inferences about the mediating roles of partnership, organizational participation, and religious belief. The approach considers the interaction between exposure and mediators, and the regression model can be expressed as:

$$E(M|A = a, C = c) = \beta_0 + \beta_1 a + \beta_2' c$$
$$E(Y|A = a, M = m, C = c) = \theta_0 + \theta_1 a + \theta_2 m + \theta_3 am + \theta_4' c$$

The controlled direct effect (CDE), natural direct effect (NDE), and natural indirect effect (NIE) in the above model, as the exposure level changes from a^* to a, can be estimated as follows:

$$CDE(m) = (\theta_1 + \theta_3 m)(a - a^*)$$
$$NDE = (\theta_1 + \theta_3 \beta_0 + \theta_3 \beta_1 a^* + \theta_3 \beta_2')(a - a^*)$$
$$NIE = (\theta_2 \beta_1 + \theta_3 \beta_1 a)(a - a^*)$$

In this study exposure A is the health shock, the two exposure levels $a = 1$ and $a^* = 0$, mediator M is partnership, organizational participation, and religious belief, respectively, Y is the subjective wellbeing of middle-aged and older adults, and C is each type of covariate. The control direct effect [CDE (m)] indicates the average degree of change in subjective wellbeing if the mediator is fixed uniformly at level m in the population, but the health shock is changed from level $a^* = 0$ to level $a = 1$. The natural direct effect indicates how much the outcome would change if the level of exposure was set at $a = 1$ instead of $a^* = 0$, but for each individual the mediator was held at the level it might have taken for that individual in the absence of exposure. The natural indirect effect shows the effect of X on Y through M if the exposure level is fixed at $a = 1$. The above effects are conditional on the level of the covariate $C = c$.

3.2 Variable selection

3.2.1 Dependent variable

Subjective wellbeing, a psychological state of contentment and pleasure, is a comprehensive cognitive evaluation of one's current quality of life and an overall subjective feedback of one's inner mental state. The variable is measured by the question "Are you happy?" and the scores are categorized into five distinct groups. A score of "0, 1, 2" is attributed a value of "1", whereas a score of "3, 4" is attributed a value of "2". A score of "5, 6" is attributed a value of "3", "7, 8" is attributed a value of "4", and "9, 10" is attributed a value of "5". The range of values spans from 1 to 5.

3.2.2 Independent variable

Health shocks. This study measures health shocks in two dimensions, chronic and acute. Chronic health shocks are measured using the question "During the past 6 months, have you had any doctor-diagnosed chronic disease?", with a "yes" answer assigned to 1 and a "no" answer assigned to 0. Acute health shocks are measured using the question "In the past year, were you ever been hospitalized due to illness", with a "yes" answer being assigned a value of 1 and a "no" answer being assigned a value of 0. Health shocks are constructed from both chronic health shocks and acute health shocks, and are assigned a value of 1 if the respondent has experienced at least one chronic or acute health shock, and 0 otherwise.

3.2.3 Mediating variable

Social participation. Based on previous research (74), three social participation dimensions—partnership, religious belief, and organizational participation—were chosen for this study. Partnership is measured by "Do you think you are popular?", with a score of 0 being the lowest and 10 being the highest. Religious belief is measured by "Are you the member of religious group?", with a value of 1 for a "yes" answer and 0 for a "no" answer. Organizational participation is measured using the questions "Are you the member of Communist Party of China?", "Are you the member of Labor union?" and "Are you the member of Association of individual

workers?". Organizational participation is assigned a value of 1 if one of the three questions is answered "yes", and 0 if all three questions are answered "no".

3.2.4 Control variables

To enhance the accuracy of examining the impact of health shocks on the subjective wellbeing of the older and middle-aged adults, and drawing from relevant research, the variables employed for control primarily encompassed demographic factors, including age, gender, education, marriage, household registration, and residence, socio-economic factors such as medical insurance, pension insurance, self-reported economic status, self-reported social status, physical health factors such as BMI and abilities in daily life (ADL), and lifestyle habits, such as smoking, drinking, exercise, siesta, and internet use. Among them, BMI is classified as underweight (BMI < 18.5), normal weight ($18.5 \leq$ BMI $<$ 24.0), overweight ($24.0 \leq$ BMI $<$ 28.0), and obese (BMI $\geq$ 28.0) according to the Health Industry Standard of the People's Republic of China, WS/T428-2013 Adult Weight Determination. The ability to perform the seven activities of daily living is based on the independent completion of outdoor activities, eating, kitchen activities, using public transport, shopping, cleaning and sanitation, and laundry, with a value of 1 if all seven activities can be completed independently and 0 otherwise.

3.3 Dataset

CFPS data from 2018 and 2020 are used in this study. An extensive, nationwide, interdisciplinary survey that focuses on Chinese households' current circumstances and changes has been conducted. The CFPS, which is supported by Peking University and the National Natural Science Foundation of China (NSF), conducts research on a wide range of subjects, including family dynamics, social engagement, education, job, migration, and health. To more accurately portray Chinese society, the CFPS employs implicit stratification and multistage probability sampling proportional to size (75). The CFPS baseline survey sample was drawn in three stages: county, village, and household, and it covered 25 provinces and districts in mainland China and 95% of the population (76). This gives us a more representative sample to investigate the influence of health shocks on the subjective wellbeing of middle-aged people and older persons. After subtracting the missing values of key variables, not applicable values, "unable to judge," "refused to answer," "don't know," and "situation not applicable" from the sample, the final number of valid samples was 8,296. The sample sizes for 2018 and 2020 are both 4,148, respectively, out of the total sample. In Table 1, we provide the sample sizes for the control and treatment groups in the two data periods.

Table 1 displays the means and mean differences for all variables before and after health shocks for both treatment and control group samples. As shown in the table, the difference in mean values of subjective wellbeing between the treatment and control groups was 0.204, 0.216, and 0.179 before exposure to health shocks, chronic health shocks, and acute health shocks, respectively, and

TABLE 1 Comparison of relevant variables between the treatment and control groups.

Variables	2018							2020						
	T	C						T	C					
		Health shocks		Chronic health shocks		Acute health shocks			Health shocks		Chronic health shocks		Acute health shocks	
	Mean	Mean	Mean diff.	Mean	Mean diff.	Mean	Mean diff.	Mean	Mean	Mean diff.	Mean	Mean diff.	Mean	Mean diff.
Subjective wellbeing	3.992	3.788	0.204***	3.776	0.216***	3.813	0.179**	4.008	3.519	0.489***	3.531	0.476***	3.493	0.515***
Partnership	7.258	7.060	0.199**	7.063	0.195*	7.053	0.205	7.239	6.728	0.511***	6.743	0.497***	6.700	0.539***
Religious belief	0.035	0.040	−0.004	0.043	−0.007	0.033	0.002	0.03	0.038	−0.008	0.043	−0.013	0.027	0.003
Organizational participation	0.099	0.079	0.019	0.079	0.019	0.080	0.019	0.116	0.075	0.041***	0.073	0.043**	0.080	0.036
Age														
45–50	0.699	0.618	0.081***	0.624	0.076***	0.607	0.093**	0.654	0.545	0.108***	0.551	0.102***	0.533	0.120***
60 years and above	0.301	0.382	−0.081***	0.376	−0.076***	0.393	−0.093**	0.346	0.455	−0.108***	0.449	−0.102***	0.467	−0.120***
Gender (1 = male)	0.524	0.439	0.085***	0.426	0.099***	0.467	0.058	0.524	0.437	0.087***	0.422	0.102***	0.467	0.058
Education														
Illiterate/semi-literate (1 = yes)	0.286	0.353	−0.067***	0.350	−0.064**	0.360	−0.074**	0.286	0.353	−0.068***	0.350	−0.064**	0.360	−0.074**
Primary school (1 = yes)	0.288	0.256	0.032	0.248	0.041	0.273	0.015	0.288	0.256	0.032	0.248	0.041	0.273	0.015
Lower secondary (1 = yes)	0.302	0.272	0.031	0.290	0.012	0.233	0.069*	0.302	0.272	0.031	0.29	0.012	0.233	0.069*
High school and above (1 = yes)	0.124	0.119	0.004	0.112	0.011	0.133	−0.01	0.124	0.119	0.005	0.112	0.012	0.133	−0.009
Household registration (1 = non-farm)	0.168	0.148	0.020	0.145	0.023	0.153	0.015	0.158	0.139	0.019	0.132	0.026	0.153	0.005
Marriage	0.924	0.912	0.013	0.898	0.027*	0.940	−0.016	0.914	0.887	0.027*	0.881	0.033*	0.900	0.014
Residence	0.417	0.406	0.010	0.406	0.011	0.407	0.010	0.423	0.406	0.017	0.399	0.023	0.420	0.003
Medical insurance	0.936	0.932	0.004	0.921	0.015	0.953	−0.017	0.874	0.879	−0.005	0.871	0.002	0.893	−0.020
Pension insurance	0.545	0.494	0.051**	0.502	0.044	0.480	0.065	0.501	0.43	0.070***	0.442	0.059**	0.407	0.094**
Self-reported economic status	3.022	2.832	0.190***	2.825	0.197***	2.847	0.175*	3.118	2.784	0.334***	2.752	0.366***	2.847	0.271***
Self-reported social status	3.257	3.130	0.127**	3.096	0.161**	3.200	0.057	3.348	3.049	0.299***	3.02	0.328***	3.107	0.241***

(Continued)

TABLE 1 (Continued)

Variables	2018							2020						
	T	C						T	C					
		Health shocks		Chronic health shocks		Acute health shocks			Health shocks		Chronic health shocks		Acute health shocks	
	Mean	Mean	Mean diff.	Mean	Mean diff.	Mean	Mean diff.	Mean	Mean	Mean diff.	Mean	Mean diff.	Mean	Mean diff.
BMI														
Underweight (1 = yes)	0.048	0.057	−0.009	0.056	−0.008	0.060	−0.012	0.043	0.064	−0.021**	0.053	−0.010	0.087	−0.044**
Normal weight (1 = yes)	0.547	0.547	0.000	0.538	0.009	0.567	−0.019	0.55	0.532	0.018	0.545	0.005	0.507	0.043
Overweight (1 = yes)	0.323	0.305	0.018	0.323	−0.001	0.267	0.056	0.329	0.311	0.017	0.310	0.018	0.313	0.015
Obese (1 = yes)	0.082	0.091	−0.009	0.083	−0.001	0.107	−0.025	0.078	0.093	−0.014	0.092	−0.014	0.093	−0.015
ADL	0.985	0.974	0.012*	0.967	0.018**	0.987	−0.002	0.766	0.687	0.079***	0.693	0.073***	0.673	0.092***
Smoking	0.347	0.294	0.053**	0.284	0.063**	0.313	0.033	0.329	0.276	0.053**	0.281	0.049*	0.267	0.062
Drinking	0.201	0.170	0.031	0.188	0.013	0.133	0.067**	0.187	0.139	0.048**	0.152	0.035	0.113	0.074**
Exercise	0.445	0.459	−0.014	0.432	0.013	0.513	−0.068*	1.000	1.000	0.000	1.000	0.000	1.000	0.000
Siesta	0.564	0.585	−0.021	0.578	−0.014	0.600	−0.036	0.639	0.687	−0.048**	0.693	−0.054*	0.673	−0.034
Internet use	0.311	0.329	−0.018	0.330	−0.019	0.327	−0.016	0.386	0.366	0.020	0.373	0.014	0.353	0.033
N	3695	453		303		150		3695	453		303		150	

*, **, and *** denote 10%, 5%, and 1% levels of significance respectively.

the difference in both increased after the experience. Acute health shocks generated the biggest difference of 0.515.

4 Results

4.1 Baseline regression

4.1.1 Propensity score matching logit estimation

The first step in using the PSM-DID method is to use the logit model to match the samples of the treatment and control groups in the base period. By controlling for the covariates affecting middle-aged people and older adults, the probability of being exposed to health shocks in the treatment and control groups after the matching is completed is similar to avoid biased estimates due to sample selectivity bias. Tables A1–A3 present the results of the propensity score estimates and balance tests for health shocks, chronic health shocks, and acute health shocks, respectively.

4.1.2 Balance test

Passing the balance test is required before using PSM-DID. According to the balance test results (Tables A1–A3), there were significant differences in the means of the characteristic variables between the treatment and control groups before matching, but the systematic deviations of the characteristic variables were all <10% after matching. Except for the medical insurance variable in Table A1, which no longer differed systematically between the treatment and control groups after matching, all variables passed the test.

To ensure matching quality, the PSM method is only valid in the common support domain. Therefore, before formally estimating the mean treatment effect, the common support hypothesis also needs to be tested to ensure that propensity scores have a sufficient number of overlapping regions in the treatment and control groups. Figure A1 illustrates the distribution of individual propensity scores for the health shock, chronic health shock, and acute health shock treatment and control group samples as well as areas of common support. Kernel density plots of propensity scores before and after matching are shown in Figures A2–A4. The treated and control groups' kernel density trends after matching are essentially the same and have a high degree of overlap compared to the pre-matching, showing that the matching findings are excellent.

4.1.3 PSM-DID analysis results

The balance test analysis shows that the PSM results are valid, thus allowing for double-differencing using the successfully matched samples. The kernel matching method was used for estimation in this paper and the results are presented in Table 2. The results demonstrate that health shocks diminish the levels of subjective wellbeing among individuals in the middle-aged and older adult cohorts. Specifically, the impact of health shocks is estimated to be a reduction of 7.4% ($-0.282/3.788 \times 100$%) in subjective wellbeing levels. In the case of chronic health shocks, the decrease is estimated at 6.9% ($-0.260/3.776 \times 100$%), while acute health shocks result in an 8.7% ($-0.332/3.813 \times 100$%) decline in

TABLE 2 Results of PSM-DID estimation of health shocks on subjective wellbeing of middle-aged people and older adults.

Variables		Health shocks	Chronic health shocks	Acute health shocks
Before	C	3.976	3.977	3.993
	T	3.785	3.776	3.812
	Diff. (T-C)	−0.191*** (0.028)	−0.202*** (0.029)	−0.181*** (0.031)
After	C	3.990	3.993	4.003
	T	3.518	3.531	3.490
	Diff. (T-C)	−0.473*** (0.028)	−0.461*** (0.029)	−0.514*** (0.031)
Diff-in-diff		−0.282*** (0.040)	−0.260*** (0.040)	−0.332*** (0.043)
Control variables		Yes		

*, **, and *** denote 10%, 5%, and 1% levels of significance respectively.

subjective wellbeing levels for middle-aged individuals and older adults. This is evident in the more severe negative consequences of acute health shocks.

4.2 Robustness check

4.2.1 Placebo test

To exclude the effects of omitted variables and potentially unobservable factors, reference was made to Chetty et al. (77), where a random sample of health shocks and subjective wellbeing were randomly selected from the total sample using the Bootstrap method to conduct a placebo test. To ensure the reliability of the estimation results, 1,000 regressions were conducted using the baseline model. According to the robustness test criteria, when the true estimated coefficients deviate from the estimated coefficients of the random sample, the benchmark results are considered to be free from model setting bias, unaffected by the interference of omitted variables, and robust. Figure A5 reports the distribution of the estimated coefficients. The coefficients obtained from the random sample estimation are all distributed around 0, indicating that the estimation results of the baseline model in this study are not affected by the interference of omitted variables.

4.2.2 Adjusting the treatment of the dependent variable

In the previous estimation, the dummy variable "subjective wellbeing" was treated as a five-category variable. This paper uses the questionnaire's original subjective wellbeing measure, or the eleven-category classification, to test the results' reliability. Table 3 displays the findings of the regression analysis of the explanatory factors for the eleven categorizations. The regression coefficients are still significant even when the explanatory variables have been treated differently, and the conclusion that acute, chronic, and health shocks all lower subjective wellbeing in middle-aged people and older persons is strong.

TABLE 3 Robustness test results.

Variables		Adjusting the treatment of subjective wellbeing			Substitution of dependent variables		
		Health shocks	Chronic health shocks	Acute health shocks	Health shocks	Chronic health shocks	Acute health shocks
Before	C	7.569	7.572	7.608	4.083	4.087	4.108
	T	7.122	7.099	7.188	3.863	3.795	4.007
	Diff. (T-C)	−0.447*** (0.064)	−0.473*** (0.065)	−0.420 (0.068)	−0.220*** (0.029)	−0.291*** (0.030)	−0.101*** (0.030)
After	C	7.607	7.611	7.636	4.158	4.159	4.176
	T	6.496	6.551	6.383	3.490	3.673	3.725
	Diff. (T-C)	−1.111*** (0.064)	−1.060*** (0.065)	−1.254*** (0.068)	−0.467*** (0.029)	−0.486*** (0.030)	−0.451*** (0.030)
Diff-in-diff		−0.664*** (0.091)	−0.587*** (0.092)	−0.834*** (0.096)	−0.248*** (0.041)	−0.195*** (0.042)	−0.350*** (0.042)
Control variables		Yes					

*, **, and *** denote 10%, 5%, and 1% levels of significance respectively.

4.2.3 Substitution of the dependent variable

Subjective wellbeing refers to an individual's personal evaluation of their current mental and life quality. It is closely related to life satisfaction, as those with elevated subjective wellbeing tend to have higher levels of life satisfaction. Hence, in this study, the life satisfaction measure was chosen as a robustness check. The regression outcomes, displayed in Table 3, demonstrate that even when substituting the dependent variable, health shocks, chronic health shocks, and acute health shocks continue to diminish the subjective wellbeing of middle-aged people and older individuals.

4.3 Heterogeneity

Based on life course theory, this study analyzed heterogeneity in four dimensions: age, gender, urban/rural and ability to perform daily activities factors. According to the findings in Table 4, four groups—people over the age of 60, women in middle and later life, rural middle-aged and senior citizens, and middle-aged and older individuals who can perform daily tasks—are more negatively impacted by health shocks, chronic health shocks, and acute health shocks.

4.4 Mechanism

For testing the mechanism, this study employs the causal mediation method (73). Table 5 lists the total effect, natural direct effect, and natural indirect effect of various health shocks on the mediating variables. According to the table, health shocks, chronic health shocks, and acute health shocks all undermine the partnership, lowering the subjective wellbeing of the middle-aged and older persons. And the mediating effects of religious belief and organizational participation are not significant. In addition, Table A4 reports the results of regressions that hypothesize an interaction between the treatment and the mediating variable, and it can be seen that the interaction term between different types of health shocks and the mediating variable has no effect on subjective wellbeing.

5 Discussion

Subjective wellbeing refers to the evaluation and assessment of one's own life (78), including reflective cognitive judgments such as life satisfaction, as well as emotional reactions to one's current life. Health status is a crucial factor affecting an individual's mood, particularly for middle-aged people and older individuals. In the field of economics, scholars have mainly focused on the relationship between income and wellbeing, with less research conducted on the impact of health shocks on the subjective wellbeing of the middle-aged and older individuals, particularly the differential impact of different types of health shocks. This study evaluates the effects and mechanisms of health shocks on the subjective wellbeing of middle-aged people and older individuals based on nationwide survey data, distinguishing between the effects of chronic health shocks and acute health shocks. Furthermore, the study analyses the heterogeneity of this impact effect across age, gender, and residence groups of middle-aged people and older adults.

The results suggest that health shocks significantly reduce subjective wellbeing in middle-aged people and older adults. Health shocks can reduce the quality of life of middle-aged people and older individuals, as well as the onset of negative emotions such as worry and sadness (79), which ultimately damage their subjective wellbeing. This paper's study interval encompasses the year 2020. Individuals who are infected with COVID-19 during this time may experience a more pronounced drop in subjective wellbeing (80). On the one hand, this is due to the COVID-19 pandemic, which surely caused a broad sense of anxiety, fear, uncertainty, and insecurity (81, 82). On the other hand, were implemented in response to COVID-19, resulting in a considerable drop in medical visits during the lockdown (83). Because of this, patients are unable to receive timely medical care, which may cause their sickness to worsen and impair their subjective feeling of wellbeing.

This study presents a novel approach by distinguishing between health shocks and examining the differences in subjective wellbeing between chronic health shocks and acute health shocks in middle-aged people and older adults. The results demonstrate that acute health shocks have a more pronounced negative impact on the subjective wellbeing of middle-aged people and older adults compared to chronic health shocks. This may be attributed to the more severe impact of acute health shocks on individuals

TABLE 4 Results of heterogeneity analysis.

			Age		Gender		Residence		ADL	
			45–59	60 years and above	Male	Female	Urban	Rural	Normal	Disabled
Health shocks	Before	C	3.940	4.050	3.947	4.006	4.046	3.920	3.979	3.457
		T	3.718	3.907	3.795	3.802	3.815	3.770	3.789	3.667
		Diff. (T-C)	−0.221*** (0.034)	−0.143*** (0.051)	−0.152*** (0.038)	−0.203*** (0.043)	−0.230*** (0.043)	−0.150*** (0.038)	−0.191*** (0.028)	0.210 (0.475)
	After	C	3.944	4.065	3.982	3.999	4.009	3.981	4.002	3.077
		T	3.465	3.599	3.603	3.458	3.597	3.464	3.512	4.000
		Diff. (T-C)	−0.478*** (0.036)	−0.466*** (0.051)	−0.379*** (0.038)	−0.541*** (0.043)	−0.412*** (0.044)	−0.518*** (0.038)	−0.490*** (0.033)	0.923 (0.964)
	Diff-in-diff		−0.257*** (0.050)	−0.324*** (0.072)	−0.226*** (0.053)	−0.337*** (0.060)	−0.182*** (0.062)	−0.368*** (0.054)	−0.300*** (0.043)	0.713 (1.075)
Chronic health shocks	Before	C	3.941	4.041	3.934	4.006	4.039	3.917	3.960	3.719
		T	3.725	3.860	3.744	3.803	3.779	3.772	3.750	3.500
		Diff. (T-C)	−0.216*** (0.034)	−0.182*** (0.052)	−0.190*** (0.038)	−0.203*** (0.043)	−0.261*** (0.044)	−0.145*** (0.038)	−0.210*** (0.033)	−0.219 (0.164)
	After	C	3.944	4.069	3.978	4.005	4.002	3.980	4.000	3.757
		T	3.527	3.570	3.594	3.491	3.539	3.514	3.510	3.750
		Diff. (T-C)	−0.417*** (0.036)	−0.499*** (0.052)	−0.384*** (0.038)	−0.513*** (0.043)	−0.463*** (0.045)	−0.466*** (0.039)	−0.491*** (0.033)	−0.007 (0.164)
	Diff-in-diff		−0.201*** (0.050)	−0.318*** (0.074)	−0.194*** (0.054)	−0.311*** (0.061)	−0.202*** (0.063)	−0.321*** (0.054)	−0.280*** (0.047)	0.213 (0.232)
Acute health shocks	Before	C	3.938	4.081	4.081	4.097	4.184	4.030	4.088	3.989
		T	3.663	4.000	3.967	4.154	3.950	4.105	4.039	4.000
		Diff. (T-C)	−0.275*** (0.039)	−0.081 (0.053)	−0.115 (0.075)	0.057 (0.086)	−0.234*** (0.089)	0.075 (0.068)	−0.049 (0.053)	0.011 (0.216)
	After	C	3.954	4.089	4.055	4.131	4.148	4.072	4.111	3.817
		T	3.337	3.661	3.633	3.692	3.850	3.595	3.857	3.750
		Diff. (T-C)	−0.616*** (0.039)	−0.428*** (0.053)	−0.421*** (0.075)	−0.439*** (0.086)	−0.298*** (0.090)	−0.477*** (0.068)	−0.254*** (0.068)	−0.067 (0.252)
	Diff-in-diff		−0.341*** (0.054)	−0.347*** (0.075)	−0.306*** (0.106)	−0.496*** (0.121)	−0.063 (0.126)	−0.553*** (0.096)	−0.206** (0.086)	−0.078 (0.332)
Control variables			Yes							

*, **, and *** denote 10%, 5%, and 1% levels of significance respectively.

TABLE 5 Results of the mechanism analysis.

	Health shocks			Chronic health shocks			Acute health shocks		
	Total effect	Natural direct effect	Natural indirect effect	Total effect	Natural direct effect	Natural indirect effect	Total effect	Natural direct effect	Natural indirect effect
Partnership	−0.291*** (0.031)	−0.244*** (0.028)	−0.047*** (0.131)	−0.287*** (0.036)	−0.249*** (0.034)	−0.038** (0.014)	−0.303*** (0.054)	−0.231*** (0.047)	−0.072** (0.028)
Religious belief	−0.291*** (0.059)	−0.290*** (0.031)	−0.001 (0.001)	−0.283** (0.092)	−0.282*** (0.037)	−0.001 (0.002)	−0.307*** (0.062)	−0.306*** (0.051)	−0.001 (0.001)
Organizational participation	−0.291*** (0.043)	−0.292*** (0.031)	0.001 (0.002)	−0.283*** (0.037)	−0.284*** (0.037)	0.001 (0.002)	−0.304** (0.102)	−0.309*** (0.051)	0.005 (0.005)
Control variables						Yes			

*, **, and *** denote 10%, 5%, and 1% levels of significance respectively.

and families, leading to reduced labor supply (84) and increased caregiving burdens on spouses or other family members, ultimately reducing leisure time (85). Such circumstances can cause feelings of guilt toward spouses and lead to lower levels of subjective wellbeing. In contrast, the weaker effect of chronic health shocks on the subjective wellbeing of middle-aged people and older adults may be attributed to the cumulative effect of chronic illness, with negative emotions becoming more prominent over time as the individual becomes chronically ill. Additionally, the number and type of chronic illnesses may also play a crucial role in the subjective wellbeing of middle-aged people and older adults. Multiple chronic illnesses increase the likelihood of hospitalization and reduce the quality of life (86, 87), whereas having only a single chronic illness has a less significant impact on subjective wellbeing.

The impact of health shocks on subjective wellbeing also varies among different groups. Regarding age, the decline in subjective wellbeing is more pronounced in older individuals over 60 years of age when they experience health shocks, chronic health shocks, and acute health shocks. This may be due to the fact that older individuals have reduced functionality compared to middle-aged individuals, exhibit more severe symptoms of illness, and recover more slowly from acute health shocks and chronic health shocks, leading to greater impairment in subjective wellbeing. In terms of gender, the decline in subjective wellbeing is more pronounced in women when they experience health shocks, chronic health shocks, and acute health shocks. Gender inequality has been studied as a form of injustice that can reduce public wellbeing (88). Women are relatively disadvantaged in terms of educational opportunities, division of labor, interpersonal network construction, and access to socio-economic resources due to traditional gender roles (89). These resources can mitigate the adverse effects of health shocks. Women are also more sensitive to stress and emotional expressions in response to negative events (90). Therefore, experiencing a negative event such as health shocks can have a more detrimental effect on the subjective wellbeing of female middle-aged individuals and older adults. As for the place of residence, the reduction in subjective wellbeing levels was more profound for middle-aged people and older individuals residing in rural areas when confronted with health shocks, whether chronic or acute. A plausible explanation for this phenomenon is that the disparity in socio-economic status impedes rural and urban middle-aged people and older individuals from enjoying equal social welfare benefits. In comparison to their urban counterparts, rural middle-aged individuals and older people are subject to inequitable policies regarding fundamental education, health care coverage, and labor market returns. Hence, when exposed to health shocks, rural middle-aged people and older individuals undergo a greater loss of subjective wellbeing due to the urban-rural differences in financial capability, public service provision, and social resource allocation. In terms of activities to daily living, health shocks, chronic health shocks, and acute health shocks have little effect on subjective wellbeing in people with impairments. As the "disability paradox" reveals (91), individuals with severe disabilities are more likely to report a higher quality of life (92, 93). Impaired persons have long evolved to coexisting with their sickness and may actively develop future representations congruent with natural decline and loss (94). Once these declines and losses occur, these expectations may have a less unfavorable psychological impact (95).

The analysis of mediating effects has revealed that partnership mediates the pathways of health shocks, chronic health shocks, and acute health shocks on the subjective wellbeing of middle-aged individuals and older adults. Health shocks cause illness distress for this demographic, which inevitably reduces their social participation. Social participation refers to a multifaceted and deep interaction with others in a society or community (96), and is a positive predictor of subjective wellbeing (97). Illness restricts an individual's interpersonal activities, diminishes the frequency of interactions with friends, and impairs partnerships. Reduced social connectedness leads to a failure to meet the spiritual demands of middle-aged and older persons (98), lowering their subjective wellbeing. One possible reason for the minor mediation impact of organizational participation and religious belief in the Chinese context is that the three types of organizations and religious groups discussed below are formal organizations. Respondents' engagement in these activities, influenced by traditional Chinese culture, implies good status symbols and hence higher motivation. As a result, the effect of health shocks on them is negligible, and hence on subjective wellbeing.

Compared to previous studies, this study has two distinctive features. Firstly, the data for this study were drawn from the CFPS, which is a well-represented national database. Secondly, the study used the PSM-DID methodology to assess the causal relationship between Health shocks and the subjective wellbeing of middle-aged individuals and older adults. This approach effectively eliminates the influence of external confounders on the assessment.

Furthermore, it is crucial to acknowledge certain limitations inherent in this study. The first pertains to the identification of individuals with chronic conditions. While respondents who experienced a chronic health shock during t0 have been excluded from the study to mitigate the inclusion of individuals who initially had a chronic disease in the control group, the available data only ensures that respondents had not received a physician's diagnosis of a chronic condition within the past 6 months at the time of the survey. This data collection, confined to a specific temporal window, fails to capture the existence of underlying chronic conditions at other junctures. Consequently, it may not accurately identify instances where a chronic condition went undiagnosed at time t0 but may indeed be chronic in nature. When this group is incorporated into the control group, they may exhibit lower subjective wellbeing at t1 compared to the control sample without a chronic condition, thereby underestimating the adverse impact of chronic health shocks on subjective wellbeing. In future studies, it would be prudent to contemplate collecting primary data and employing more comprehensive and diversified measures of chronic diseases to comprehensively identify potential individuals with chronic conditions, thereby enhancing the scientific rigor of our research.

Secondly, with regard to the disparity in subjective wellbeing between the middle-aged and older cohorts, the measurement questions pertaining to chronic health shocks and acute health shocks in the CFPS questionnaire solely ascertain whether the sample experienced a negative health event or not. However, these questions do not account for the intensity or magnitude of chronic health shocks or acute health shocks. Regrettably, this limitation impedes our ability to measure whether the divergence in subjective wellbeing between the middle-aged and older adults is

attributable to varying degrees of chronic and acute health shocks. In future studies, it may be worthwhile to consider collecting additional data on the strength of chronic and acute health shocks to more effectively discern the underlying factors contributing to the differences in subjective wellbeing between the middle-aged and the older.

Third, there are common causes of worsening in health and spousal fatalities that can be significantly age-graded. However, due to the limitations of the study data, the sample size of older persons aged 75 and up in the study sample was modest. As a result, this study was unable to investigate the variations in subjective wellbeing between the young old (60–74 years old) and the old old (75–89 years old) following various forms of health shocks. The reasons for the disparities in subjective wellbeing between younger and older persons can be investigated further in future studies by integrating more age groups in the questionnaire data collection.

Finally, mediation analyses assume no uncontrolled confounding between exposure and outcome, exposure and mediator, and mediator and outcome. Validating and supporting these assumptions is difficult in most mediation analyses, including the present study. Although factors that may influence the mediated effect-outcome relationship were controlled for as much as possible in the study model, some uncontrolled confounding may still exist, and possible potential factors can be further identified in subsequent studies, such as through questionnaires or experimental design.

Furthermore, due to the limits of the research data, we were unable to accurately comprehend the frequency of social activity participation and data connected to the study respondents' happiness with social participation. As a result, we were unable to assess the quantity and quality of respondents' social participation in greater depth and discriminate between the social participation of middle-aged people and old persons. The questionnaire method can be utilized in future study to examine differences in the amount and quality of social participation among different groups.

These results also have policy implications. From a service standpoint, the government should improve the development of an integrated medical service system. This will not only promote a more equitable distribution of high-quality medical resources, but will also help to improve the quality of medical services offered by grassroots organizations. In this approach, they may better maintain their health data, provide individualized health recommendations, and prevent the incidence of common and frequent diseases in the middle-aged and older population before they are impacted by health shocks. After middle-aged individuals and older persons have avoided any health shocks, those who have been unwell can receive effective and timely treatment. On the demand side, the government should strengthen the appropriate outpatient medical insurance system, major illness insurance system, and commercial insurance system in order to protect the medical needs of the middle-aged and older adults. Minor illnesses can be easily avoided if middle-aged individuals and older people receive timely outpatient treatment. Improving the major illness insurance system can also ensure that persons in their forties and fifties who have already become unwell receive timely medical treatment. Adopting a healthy lifestyle is critical for people and families to avoid health shocks.

This involves eating a well-balanced diet, exercising moderately, getting enough sleep, and avoiding unhealthy behaviors (such as smoking and alcohol misuse). Being socially active is also crucial. Social participation gives support, relieves stress, and increases social capital, all of which contribute to an individual's subjective wellbeing.

6 Conclusion

This study aims to evaluate the influence of health shocks on changes in subjective wellbeing among middle-aged individuals and older adults (aged 45+) in China. The study is based on a nationally representative survey, CFPS, utilizing the PSM-DID model. The findings suggest that health shocks can adversely impact the subjective wellbeing of this demographic by affecting their personal relationships. Therefore, interventions aimed at maintaining or elevating the levels of subjective wellbeing among at-risk individuals should be implemented proactively, before the onset of a health shock.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: http://www.isss.pku.edu.cn/cfps/download.

Author contributions

CJ, QX, and HG were responsible for literature research and data analysis. Material preparation and data collection were done by HC. The first draft of the manuscript was written by QX, the revision of the literature review and policy recommendations was done by JG, and the data checking and graph organization was done by ZL. All authors commented on a previous version of the manuscript and were involved in the conceptualization and design of the study. All authors read and approved the final manuscript.

Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1238026/full#supplementary-material

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