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Active and healthy aging and quality of life: Interventions and outlook for the future, volume II

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Active and healthy aging and quality of life: Interventions and outlook for the future, volume II

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The elderly's satisfaction with physical activity programs in senior welfare centers

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Introduction: Healthcare for the aging population has become a crucial issue in South Korea to maintain the elderly's quality of life, and physical activity is of primary importance for older adults. This study evaluated the exercise characteristics and satisfaction of the elderly who participated in physical activity programs provided by senior welfare centers in South Korea.

Methods: We surveyed 266 participants to learn the characteristics of the elderly's exercise participation and their satisfaction with instructors, exercise programs, and facilities provided by senior welfare centers. A total of 263 copies were analyzed using the SPSS 23.0 statistical software.

Results and discussion: The top three physical activity programs that the elderly participated in senior welfare centers were dancing (25.3%), gymnastics (24.8%), and table tennis/badminton (13.2%). There were significant differences in respondents' satisfaction according to sex, education level, spouse, family type, and monthly income per household ($p < 0.05$). The elderly were satisfied with programs (4.183 ± 0.483), facilities (3.881 ± 0.483), and instructors (3.604 ± 0.483) in order. Also, this study shows that user satisfaction differs depending on the demographic characteristics (gender, education, marital status, family type, economic status) and the characteristics of the exercise participation of the elderly (exercise duration, participation period).

Conclusions: In conclusion, we presented the elderly's satisfaction with physical activity programs in senior welfare centers, suggesting that the elderly need physical activity programs according to their demographic and exercise characteristics.

KEYWORDS

elderly, user satisfaction, physical activity, program, senior welfare centers

1. Introduction

The proportion of older people in the population is reported to increase in all highly mechanized countries worldwide (1). Among the Organization for Economic Co-operation and Development (OECD) countries, South Korea is the fastest aging country (2). Healthcare for the aging population has become a crucial issue in South Korea to maintain older adults' quality of life, and physical activity is of primary importance for older adults (3). A strong connection has been noted between increased physical inactivity and chronic diseases (4). With age and physical inactivity, increased insulin resistance and decreased lipoprotein lipase activity in the skeletal musculature can lead to chronic diseases such as atherosclerosis (5), with follow-up effects such as myocardial insufficiency, coronary heart disease, hypertension, stroke, and type II diabetes (6, 7). Furthermore, higher physical activity levels are associated with better cognitive function in older adults (1). Being

physically active and/or engaging in regular exercise are positively related to indicators of healthy aging (8). Since the aging process is associated with deterioration in several biological systems, the elderly are required to perform daily activities at a higher percentage of their maximum physiological reserve (9). Thus, regular physical activity can help improve physical and mental functions as well as reverse some effects of chronic disease to keep older people mobile and independent (10). In addition, successful aging is an important concept for describing the quality of aging (11). Successful aging can be defined as high physical, psychological, and social functioning in old age without major diseases (12). Moreover, physical activity is known to support successful aging (13). The more active people are in their later years, the greater their life satisfaction (14). Furthermore, physical activity is associated with improved quality of life among older individuals (15).

Although regular physical activity is essential for maintaining long-term physical, cognitive, and emotional health for the elderly, few older adults engage in routine physical activity (16). For example, ∼80% of Korean older adults aged 60–70 years do not engage in moderate physical activity and 90% of older adults over 71 years of age are inactive (17). Also, it is clear that the elderly become cognizant of their age-related physical limitations, and their awareness radiates into a lack of confidence in their abilities (18). They are likely to have uncertainty about what activities are safe, as well as fear of injury, pain, overexertion, or prolonged recovery. For this reason, lack of professional guidance (e.g., instructors, programs, and facilities) served as a major barrier to physical activity in general (16). In particular, health programs provided by senior welfare centers and community facilities contribute to increased physical activity and promote improved quality of life among the elderly (19). Meanwhile, participation in physical activity in the elderly can be influenced by a number of variables including demographic factors such as gender, education, and marital status (17). For example, physical activity participation is lower among older females (20) and less educated older seniors (21). Choices of older adults to be regularly physically active are also influenced by social support from family members or friends, availability of facilities for exercise and/or recreational activities, personal determinants especially one's motivation, self-efficacy, and self-regulation skills (17). In particular, user participation is related to user satisfaction (18). User satisfaction is a term frequently used in marketing (22). Satisfaction is defined as an effective statement about emotional reactions to the experience of products and services, which is influenced by user satisfaction with these products or services and by the information used to select products or services (23). Therefore, in order to increase the participation rate of programs promoting physical activity among the elderly attending senior welfare centers, an evaluation of user satisfaction will be needed. Studies on physical activity with seniors have mostly focused on programs, mental health, including depression and anxiety, and demographic factors (17, 24, 25). However, few studies have analyzed the reasons for not participating in physical activities provided by senior centers in terms of user satisfaction. Considering this, we analyzed the elderly's satisfaction with physical activity programs in senior welfare centers in Korea. Thus, this study was conducted to contribute to the promotion of physical activity of the elderly by increasing their satisfaction with the program of senior welfare centers.

2. Materials and methods

2.1. Research design

This descriptive study examined the user satisfaction of the elderly aged 65 years or older who participated in exercise programs of senior welfare centers in South Korea during the COVID-19 pandemic. The null hypothesis (H_0) is that the demographic characteristics and the characteristics of the exercise participation of the elderly are unrelated to user satisfaction. Therefore, this study presents and verifies the following alternative hypotheses:

***H*$_1$**. *User satisfaction will differ depending on the demographic characteristics of the elderly.*
***H*$_2$**. *User satisfaction will differ depending on the characteristics of the exercise participation of the elderly.*

2.2. Participants

This study was conducted in compliance with the ethical issues presented in the Declaration of Helsinki, according to the guidelines of the Korean government that general surveys are not subject to review by the institutional review board. Thus, this study was conducted after obtaining voluntary consent from the elderly at two senior welfare centers in Seoul or Suwon, South Korea. The minimum sample size was obtained using G*power 3.1.9.2, based on previous studies (26, 27). With a significance level of 0.05, power of 0.95, and an effect size of 0.30, the minimum sample size was confirmed to be 242. Therefore, 266 participants were recruited, considering a dropout probability of 10 percent. Among these, three responses deemed insincere were excluded, resulting in 263 valid responses for analysis.

Table 1 shows participants' demographic characteristics. Of the 263 participants in this study, 154 (58.6%) were women, and 82 (31.2%) were between 71 and 75 years of age. Moreover, 151 (57.4%) had a spouse, and 54 (20.5%) respondents were living alone. One hundred thirty-three people (50.6%) had a monthly income per household of <1 million won (about $700). This suggests that some elderly adults are lonely or economically poor.

2.3. Research instrument

A questionnaire was developed based on previous studies (28–30). The questionnaire contained 29 items, which consisted of three sections of questions related to the following dimensions: demographic variables, exercise participation characteristics, and user satisfaction. Responses were scored on a Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). An exploratory factor analysis was performed to analyze the validity of the instrument, and Cronbach's α was extracted for the analysis (Table 2). The principal component

TABLE 1 Participants' demographic characteristics.

Variable	Category	Frequency (*n*)	Percentage (%)
Gender	Male	109	41.4
	Female	154	58.6
Age (years)	66–70	55	20.9
	71–75	82	31.2
	76–80	73	27.7
	≥81	53	20.2
Education level	Middle school graduate or lower	130	49.4
	High school graduate	95	36.1
	University graduate or higher	38	14.5
Presence of a spouse	Yes	151	57.4
	No	112	42.6
Family type	Living alone	54	20.5
	Living with direct descendants (one generation)	112	42.5
	Living with direct descendants (two generations)	70	26.7
	Living with direct descendants (three generations)	28	10.3
Monthly income per household	1,000,000 KRW or less	133	50.6
	1,000,001–2,000,000 KRW	47	17.9
	2,000,001–3,000,000 KRW	43	16.3
	3,000,001–4,000,000 KRW	20	7.6
	4,000,001 KRW or more	20	7.6
Total		263	100

KRW is the Korean currency unit. One dollar (USD) is equivalent to about 1,300KRW (as of August 2022).

method was used for exploratory factor analysis to estimate factor loading, and the varimax method was selected as the rotation method.

The results demonstrated that all factors had a loading value of 0.7 or more for each questionnaire item, and the eigenvalue of each factor exceeded 1.0. In addition, Cronbach's αs for all items exceeded 0.8, indicating high reliability. Furthermore, Kaiser-Meyer-Olkin (KMO) is a value indicating the degree to which the correlation between variables is well explained by other variables. Because the KMO values of each variable are all >0.7, it can be interpreted that the selection of variables was good. Furthermore, the results of Bartlett's test indicated that the factor analysis model was suitable.

2.4. Data collection and analysis

The survey was conducted from August 1 to August 31, 2022, using a convenience sampling of South Korean men and women aged 65 years or older who regularly visited senior welfare centers during the COVID-19 pandemic. Written informed consent was obtained from the respondents, and data were collected using a structured questionnaire. A total of 263 copies were used for data analysis and data analysis was conducted through Statistical Package for the Social Sciences (SPSS) 23.0 statistical software (IBM, Armonk, NY, USA). Descriptive statistics such as mean, standard deviation, and frequency distribution were used at the descriptive level. In addition, one-way analysis of variance (ANOVAs) and Scheffé's *post hoc* pairwise comparison analyses were performed. Significance was set at 0.05.

3. Results

3.1. Participants' exercise participation characteristics

Table 3 shows the exercise participation characteristics of the respondents. Ninety-three respondents (35.3%) answered that they exercised 4–5 times a week at senior welfare centers. One-hundred twenty-eight respondents (48.6%) said they practiced 31 to 60 min per session. Ninety-one respondents (34.6%) answered that the exercise duration was "13–36 months." A total of 204 (77.5%) respondents replied that healthcare was the primary purpose for participating in the physical activity program. Lastly, 168 (63.8%) answered that they mainly obtained information through word of mouth.

In addition, the results of the multiple response frequency analysis to determine what programs the elderly who participate in physical activity programs at the senior welfare center most frequently participate in. The top three physical activity programs were dancing (25.3%), gymnastics (24.8%), and table tennis/badminton (13.2%).

3.2. Analysis of satisfaction differences by demographic characteristics

Table 4 presents participants' satisfaction according to their demographic variables. In order, participants were satisfied with programs, facilities, and instructors, showing the results of the one-way ANOVA for satisfaction by demographic characteristics. There were significant differences in respondents' satisfaction according to sex, education level, spouse, family type, and monthly income per household. First, concerning gender, satisfaction with instructors was higher among men (3.672 ± 0.464) than women (3.527 ± 0.717; $p < 0.001$), satisfaction with programs was higher among women (4.314 ± 0.579) than men (4.042 ± 0.474; $p = 0.001$), and satisfaction with facilities was higher among women (3.971 ± 0.482) than men (3.793 ± 0.382; $p = 0.038$). Second, concerning age, there were no significant differences in satisfaction with instructors, programs, or facilities. Third, concerning education level, there was no difference in satisfaction with instructors;

TABLE 2 Results of the validity and reliability analysis.

Category	Item	Rotated component matrix (varimax)		
		Factor 1	Factor 2	Factor 3
Satisfaction with instructors	Instructors' counseling experience	0.749	0.151	0.063
	Appropriate assessment of instructors	0.893	0.156	0.134
	Trust in instructors	0.844	0.124	0.111
	Instructors' exact knowledge	0.845	0.031	0.206
	Kind manner of instructors	0.724	0.052	0.217
Satisfaction with programs	Segmentation of programs	0.051	0.914	0.192
	Suitability of programs	0.023	0.776	0.215
	Benefits of programs	0.159	0.851	0.167
	Diversity of programs	0.173	0.762	0.218
	Appropriate program fees	0.116	0.921	0.111
Satisfaction with facilities	Equipment of facilities	0.167	0.138	0.798
	Cleanliness in facilities	0.154	0.048	0.803
	Sufficient space in facilities	0.201	0.127	0.812
	Transportation to facilities	0.167	0.103	0.734
	Changing rooms and shower rooms in facilities	0.104	0.252	0.791
	Information on use of facilities	0.148	0.113	0.763
Eigenvalues		7.932	1.638	1.301
Variance %		49.671	9.892	7.668
Accumulated %		49.671	59.563	67.231
Cronbach's α		0.904	0.872	0.856

Kaiser-Meyer-Olkin test = 0.852.
Bartlett's test = 4.738 ($p<0.001$).

however, satisfaction with the programs (4.304 ± 0.594 vs. 3.758 ± 0.458; $p < 0.001$) and satisfaction with facilities (4.037 ± 0.338 vs. 3.657 ± 0.426; $p = 0.002$) were significantly higher in the low education group than in the high education group, respectively. These results were confirmed using Scheffé's *post-hoc* test. Fourth, concerning the presence of a spouse, satisfaction with the instructor was significantly higher in the group without a spouse (3.872 ± 0.713) than in the group with a spouse (3.463 ± 0.589; $p = 0.001$), satisfaction with the program was significantly higher in the group without a spouse (4.313 ± 0.634) than in the group with a spouse (4.123 ± 0.672; $p = 0.018$), and satisfaction with facilities was significantly higher in the group without a spouse (4.051 ± 0.627) than in the group with a spouse (3.789 ± 0.463; $p = 0.003$). Fifth, concerning family type, those living for three generations had higher satisfaction with the instructors (4.046 ± 0.589; $p < 0.001$), programs (4.388 ± 0.672; $p = 0.007$), and facilities (4.112 ± 0.463; $p = 0.001$) than did their counterparts. These results were confirmed by Scheffé's *post-hoc* test. Sixth, concerning monthly income per household, those who made 3,000,001–4,000,000 won had higher satisfaction with instructors (4.219 ± 0.723; $p = 0.002$) as compared to the other groups. Those who made 4,000,000 won or more were most satisfied with the program (4.468 ± 0.483; $p = 0.046$) as compared to the other groups. However, there was no significant difference in satisfaction with facilities among the groups.

3.3. Analysis of satisfaction differences by exercise participation characteristics

Table 5 presents the means and standard deviations for each satisfaction level, based on respondents' exercise participation characteristics, showing the results of the one-way ANOVA for satisfaction by exercise participation characteristics. Overall, participants were satisfied with programs (4.183 ± 0.483), facilities (3.881 ± 0.483), and instructors (3.604 ± 0.483) in order. In this study, the following results were derived. First, concerning exercise frequency, there were no significant differences between groups for satisfaction with instructors, programs, or facilities. Second, concerning exercise duration, those in the "91–120 min" group had more satisfaction with instructors (3.873 ± 0.459) than those in the other groups, while those in the "≤30 min" group (2.943 ± 0.522) had the lowest level of satisfaction with instructors. This was verified through Scheffé's *post-hoc* test. There were no significant differences between groups for satisfaction with programs or facilities. Third, concerning the participation period, those in the "37–60 months" group had greater satisfaction with instructors (3.922 ± 0.723) as compared to those in the other groups, while the "≤12 months" group (2.943 ± 0.522) had the lowest level of satisfaction with instructors. This was verified through Scheffé's *post-hoc* test. Moreover, those in the "13–36 months" group had

TABLE 3 Respondents' exercise participation characteristics.

Variable	Category	Frequency (*n*)	Percentage (%)
Exercise frequency	Once a week	9	3.4
	2–3 times a week	81	30.7
	4–5 times a week	93	35.3
	6–7 times a week	80	30.4
Exercise duration	30 min or less	35	13.3
	31–60 min	128	48.6
	61–90 min	38	14.4
	91–120 min	30	11.4
	121 min or more	32	12.1
Participation period	12 months or less	70	26.6
	13–36 months	91	34.6
	37–60 months	52	19.7
	61 months or more	50	19.1
Exercise purpose	Healthcare	204	77.5
	Physical rehabilitation	11	4.1
	Use of leisure time	30	11.4
	Other (friending, relieving stress, etc.)	18	6.8
Method of obtaining information	Leaflet advertising	32	12.1
	Mobile advertising	27	10.2
	Word of mouth	168	63.8
	Other	36	13.6
Total		263	100

greater satisfaction with programs (4.312 ± 0.634) as compared to those in the other groups, while the "≤12 months" group (4.034 ± 0.672) scored the lowest. This was verified through Scheffé's *post-hoc* test. There was no significant difference in satisfaction with facilities among the groups.

3.4. Discussion

Physical activity can be defined as voluntary body movements which are produced by skeletal muscles, resulting in the increase in energy consumption (31). Physical activity has been a key part of active aging and the association between exercise and physical health is well established (19). In particular, exercise at advanced ages is important for maintaining physical fitness, promoting mobility, preventing falls, and providing access to opportunities that help personal independence (32). It is also reported that regular exercise had significant effects on elderly's self-consistency (33), and physical activity was significantly related to life satisfaction and happiness in the elderly (34, 35). Moreover, physical activity can improve quality of life and wellbeing of the elderly when compared with minimal or no-treatment controls (36). Previous studies suggested that the elderly in urban areas used the public exercise facilities regardless of their perceived health and that they preferred low-intensity exercises (37, 38). While reviewing these literature on the necessity of physical activity for the elderly, we paid attention to senior welfare centers in Korea. Senior welfare centers, also commonly known as senior centers, elderly centers or seniors' clubs, offer a wide variety of programs and services (39). By offering opportunities for social interaction and friendship, senior welfare centers have traditionally had a central role in easing loneliness, increasing social integration and reducing isolation (19, 40). In addition, institutions similar to the senior welfare centers in Korea have been operating in many developed countries to promote the welfare of the elderly. For example, ∼15,000 community senior centers in the United States have given a wide range of services for seniors to improve their overall health and wellness in their community (41, 42). In this regard, there is a need to investigate users' satisfaction with the exercise programs provided to promote the health of the elderly in senior welfare centers.

This study examined the satisfaction of South Korean senior citizens (aged 65 years or older, mean age: 74.7 ± 1.483) with the physical activity programs provided by senior welfare centers during the COVID-19 pandemic. We evaluated user satisfaction with instructors, programs, and facilities according to demographic factors such as gender, age, education, presence of a spouse, family type, and monthly income per household attending senior welfare centers. This study confirmed that user satisfaction could be different according to all demographic factors except the age of the elderly. This finding indirectly supports the results of previous studies (17, 20, 21), which showed that a number of variables, including demographic factors such as gender, education, and marital status, could influence the participation in physical activity of the elderly. The most common responses for exercise participation at the senior welfare centers were exercising 4–5 times a week (35.3%), for 31–60 min (48.6%), and for over 13–36 months (34.6%). The top three physical activity programs that the elderly participated in senior welfare centers were dancing (25.3%), gymnastics (24.8%), and table tennis/badminton (13.2%). These preferences may vary depending on the size of the facility of the senior welfare center (e.g., swimming), but the top three exercise programs could be preferred by the respondents as they are suitable for the elderly with low strength and agility. In particular, dancing is an effective physical activity for improving static and dynamic balance control in the elderly, which is consistent with the previous study (43).

This study shows that user satisfaction differs depending on the demographic characteristics (gender, education, marital status, family type, economic status). Particularly, females were significantly less satisfied with instructors (3.527 ± 0.717) than males(3.672 ± 0.464), which was statistically significant ($p < 0.001$). Of the 263 participants in this study, 154 (58.6%) were female, and 109 (41.4%) were male. This finding is inconsistent with the results of Marquet et al. (20), who reported that physical activity participation was lower among older females. It could be related to the selection bias since we included only subjects attending two senior welfare centers located in the metropolitan

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TABLE 4 Results of the one-way analysis of variance (ANOVA) for user satisfaction with the demographic characteristics of the elderly.

Category		Subcategory	Mean ± standard deviation	*F*	*P*	*Post-hoc*
Gender	Satisfaction with instructors	Male[a]	3.672 ± 0.464	22.271	<0.001***	a>b
		Female[b]	3.527 ± 0.717			
	Satisfaction with programs	Male[a]	4.042 ± 0.474	10.923	0.002**	b>a
		Female[b]	4.314 ± 0.579			
	Satisfaction with facilities	Male[a]	3.793 ± 0.382	4.903	0.038*	b>a
		Female[b]	3.971 ± 0.482			
Age	Satisfaction with instructors	66–70[a]	3.781 ± 0.445	1.453	0.229	(-)
		71–75[b]	3.464 ± 0.436			
		76–80[c]	3.621 ± 0.522			
		≥81[d]	3.763 ± 0.533			
	Satisfaction with programs	66–70[a]	4.127 ± 0.724	0.493	0.726	(-)
		71–75[b]	4.201 ± 0.733			
		76–80[c]	4.208 ± 0.488			
		≥81[d]	4.268 ± 0.778			
	Satisfaction with facilities	66–70[a]	3.801 ± 0.718	1.509	0.223	(-)
		71–75[b]	3.824 ± 0.661			
		76–80[c]	3.946 ± 0.583			
		≥81[d]	4.029 ± 0.421			
Education level	Satisfaction with instructors	Middle school graduate or lower[a]	3.654 ± 0.532	2.754	0.077	(-)
		High school graduate[b]	3.743 ± 0.459			
		University graduate or higher[c]	3.346 ± 0.495			
	Satisfaction with programs	Middle school graduate or lower[a]	4.304 ± 0.594	12.387	<0.001***	a > b > c
		High school graduate[b]	4.246 ± 0.784			
		University graduate or higher[c]	3.758 ± 0.458			
	Satisfaction with facilities	Middle school graduate or lower[a]	4.037 ± 0.338	6.701	0.002**	a > b > c
		High school graduate[b]	3.792 ± 0.632			
		University graduate or higher[c]	3.657 ± 0.426			
Presence of a spouse	Satisfaction with instructors	Yes[a]	3.463 ± 0.589	11.791	0.002**	b>a
		No[b]	3.872 ± 0.713			
	Satisfaction with programs	Yes[a]	4.123 ± 0.672	5.587	0.018	(-)
		No[b]	4.313 ± 0.634			
	Satisfaction with facilities	Yes[a]	3.789 ± 0.463	9.142	0.003**	b>a
		No[b]	4.051 ± 0.627			
Family type	Satisfaction with instructors	Living alone[a]	3.891 ± 0.723	7.728	<0.001***	d >a >c > b
		Living with direct descendants (one generation)[b]	3.322 ± 0.483			

(Continued)

TABLE 4 (Continued)

Category		Subcategory	Mean ± standard deviation	*F*	*P*	*Post-hoc*
		Living with direct descendants (two generations)[c]	3.754 ± 0.495			
		Living with direct descendants (three generations)[d]	4.046 ± 0.589			
	Satisfaction with programs	Living alone[a]	4.377 ± 0.723	3.898	0.007**	d > a > c > b
		Living with direct descendants (one generation)[b]	4.068 ± 0.483			
		Living with direct descendants (two generations)[c]	4.179 ± 0.458			
		Living with direct descendants (three generations)[d]	4.388 ± 0.672			
	Satisfaction with facilities	Living alone[a]	4.109 ± 0.481	4.832	0.003**	d >a >c > b
		Living with direct descendants (one generation)[b]	3.739 ± 0.416			
		Living with direct descendants (two generations)[c]	3.887 ± 0.426			
		Living with direct descendants (three generations)[d]	4.112 ± 0.463			
Monthly income per household	Satisfaction with instructors	1,000,000 KRW or less[a]	3.467 ± 0.495	4.931	0.002**	d >e >c >b > a
		1,000,001–2,000,000 KRW[b]	3.501 ± 0.589			
		2,000,001–3,000,000 KRW[c]	3.849 ± 0.713			
		3,000,001–4,000,000 KRW[d]	4.219 ± 0.723			
		4,000,001 KRW or more[e]	4.018 ± 0.483			
	Satisfaction with programs	1,000,000 KRW or less[a]	4.157 ± 0.458	2.436	0.046*	e> d >c >a >b
		1,000,001–2,000,000 KRW[b]	4.068 ± 0.672			
		2,000,001–3,000,000 KRW[c]	4.209 ± 0.634			
		3,000,001–4,000,000 KRW[d]	4.221 ± 0.723			
		4,000,001 KRW or more[e]	4.468 ± 0.483			
	Satisfaction with facilities	1,000,000 KRW or less[a]	3.892 ± 0.426	2.217	0.067	(-)
		1,000,001–2,000,000 KRW[b]	3.749 ± 0.463			
		2,000,001–3,000,000 KRW[c]	3.838 ± 0.627			
		3,000,001–4,000,000 KRW[d]	4.168 ± 0.481			
		4,000,001 KRW or more[e]	4.159 ± 0.416			

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

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TABLE 5 Results of the one-way analysis of variance (ANOVA) for user satisfaction with the characteristics of the exercise participation of the elderly.

Category		Subcategory	Mean ± standard deviation	*F*	*P*	*post-hoc*
Exercise frequency	Satisfaction with instructors	Once a week[a]	3.672 ± 0.464	1.512	0.211	(-)
		2–3 times a week[b]	3.527 ± 0.717			
		4–5 times a week[c]	3.813 ± 0.445			
		6–7 times a week[d]	3.544 ± 0.436			
	Satisfaction with programs	Once a week[a]	4.042 ± 0.474	1.523	0.209	(-)
		2–3 times a week[b]	4.073 ± 0.579			
		4–5 times a week[c]	4.276 ± 0.724			
		6–7 times a week[d]	4.271 ± 0.733			
	Satisfaction with facilities	Once a week[a]	3.743 ± 0.371	2.284	0.098	(-)
		2–3 times a week[b]	3.712 ± 0.482			
		4–5 times a week[c]	3.981 ± 0.718			
		6–7 times a week[d]	3.834 ± 0.661			
Exercise duration	Satisfaction with instructors	≤30 min[a]	2.943 ± 0.522	5.913	<0.001***	d> c>b>e> a
		31–60 min[b]	3.747 ± 0.533			
		61–90 min[c]	3.817 ± 0.532			
		91–120 min[d]	3.873 ± 0.459			
		≥121 min[e]	3.432 ± 0.495			
	Satisfaction with programs	≤30 min[a]	3.961 ± 0.488	1.983	0.098	(-)
		31–60 min[b]	4.214 ± 0.778			
		61–90 min[c]	4.146 ± 0.594			
		91–120 min[d]	4.377 ± 0.784			
		≥121 min[e]	4.342 ± 0.458			
	Satisfaction with facilities	≤30 min[a]	3.712 ± 0.583	1.139	0.344	(-)
		31–60 min[b]	3.922 ± 0.421			
		61–90 min[c]	3.931 ± 0.338			
		91–120 min[d]	4.011 ± 0.632			
		≥121 min[e]	3.928 ± 0.426			
Participation period	Satisfaction with instructors	≤12 months[a]	3.313 ± 0.589	4.753	0.004**	c>b >d>a
		13–36 months[b]	3.752 ± 0.713			
		37–60 months[c]	3.922 ± 0.723			
		≥61 months[d]	3.512 ± 0.483			
	Satisfaction with programs	≤12 months[a]	4.034 ± 0.672	2.587	0.049*	b>c>d> a
		13–36 months[b]	4.312 ± 0.634			
		37–60 months[c]	4.281 ± 0.723			
		≥61 months[d]	4.192 ± 0.483			
	Satisfaction with facilities	≤12 months[a]	3.843 ± 0.463	1.031	0.382	(-)
		13–36 months[b]	3.901 ± 0.627			
		37–60 months[c]	4.094 ± 0.481			
		≥ 61 months[d]	3.828 ± 0.416			

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

area in Korea. The elderly with a higher level of education showed significantly lower satisfaction with exercise programs (3.758 ± 0.458) and facilities (3.657 ± 0.426) than other groups. In addition, it was found that the elderly with spouses were less satisfied with instructors (3.463 ± 0.589) and facilities (3.789 ± 0.463). The elderly living with direct descendants (one generation) showed

the lowest level of satisfaction with instructors (3.322 ± 0.483), exercise programs (4.068 ± 0.483), and facilities (3.739 ± 0.416) during physical activities at senior welfare centers ($p < 0.01$). We also confirmed that the elderly with low household incomes (2 million won or less) were less satisfied with instructors (3.467 ± 0.495) or programs (4.068 ± 0.672). Our findings support the results of Tsou and Liu (44) who presented that individuals with a low income or who are unemployed have lower life satisfaction. This study also shows that user satisfaction can differ depending on the characteristics of the exercise participation of the elderly. For example, user satisfaction with the instructors was significantly lower in the elderly group (2.943 ± 0.522) who exercised <30 min ($p < 0.001$). These findings suggest that instructors' roles should be changed for the elderly with 30 min of exercise. In addition, it was confirmed that satisfaction with the instructors (3.313 ± 0.589) and exercise programs (3.313 ± 0.589) was relatively lower in the exercise group for <1 year compared to other groups. It was also confirmed that the elderly who attended senior welfare centers for more than 5 years were relatively less satisfied with the instructors (3.512 ± 0.483) and exercise programs (4.192 ± 0.483) than other groups. Therefore, it can be seen that the selection of instructors and changes in teaching methods or exercise programs are required for the elderly who have participated for more than 5 years. In our study, exercise frequency and exercise intensity were not related to user satisfaction of the elderly with exercise programs or facilities. This did not match the research results of An et al. (34), which reported that participants with a higher physical activity level tended to have higher life satisfaction and happiness, which could be related to their different indicators (life satisfaction vs. user satisfaction).

Based on the results, this study could suggest the following improvement plans. First, more diverse methods should be developed for the elderly to obtain information on senior welfare center programs. Second, it is necessary to find a way to increase older men's satisfaction with physical activity programs at senior welfare centers, since they prefer more active exercise than women. Third, senior welfare centers had better develop segmented programs according to the elderly's physical strength and age, providing appropriate exercise instructors and secure safe and convenient facilities for the elderly. However, since muscle weakness in the elderly threatens health (45), it is necessary to consider exercises to strengthen the muscles of the elderly when organizing exercise programs in senior welfare centers. Second, there were differences in user satisfaction according to sex, education level, spouse, family type, and household income. However, the difference in satisfaction between the groups according to age was not significant. It has been reported that life satisfaction has a negative propensity with age, which differs from the results of this study—that exercise satisfaction is independent of age (46). Third, the differences in satisfaction among the groups according to exercise duration and participation period were significant. However, there was no significant difference among the groups in satisfaction with exercise frequency. Therefore, careful consideration is required for elderly individuals who regularly exercise at senior welfare centers. Based on these results, the hypotheses of this study could be verified as follows. First, hypothesis 1, that user satisfaction will differ depending on the demographic characteristics of the elderly, is partially accepted. Second, hypothesis 2, that user satisfaction will differ depending on the characteristics of the exercise participation of the elderly, is also partially accepted.

4. Conclusions

This study was conducted to identify problems and improvement plans for physical activity programs in senior welfare centers considering participants' satisfaction with the instructors, programs, and facilities. We recruited 266 participants attending two senior welfare centers in a metropolitan area in Korea, and 263 valid responses were analyzed. As a result, we report that user satisfaction differs depending on the demographic characteristics including gender, education, marital status, family type, and economic status, presenting the characteristics of the exercise participation of the elderly, such as exercise duration and participation period. This study also shows a strategy for physical activity programs in senior welfare centers, suggesting that it is necessary to provide physical activity programs for the elderly in senior welfare centers according to their demographic and exercise characteristics. Thus, this research is differentiated from other studies in that it evaluated the elderly's user satisfaction with instructors, exercise programs, and facilities according to demographic characteristics and the characteristic of the exercise participation, suggesting the need to improve items with low user satisfaction among the elderly.

This study contributed to the literature by identifying and examining user satisfaction that plays a role in facilitating or hampering the elderly's participation in senior welfare centers. However, there is a limitation in generalization in that it investigated only physical activity programs provided at two senior welfare centers in the Seoul metropolitan area during the COVID-19 pandemic. Thus, follow-up studies should be conducted, including various ages and regions. Nevertheless, this study is meaningful in that it investigated the exercise characteristics and satisfaction of the elderly attending physical activity programs at senior welfare centers and suggested improvement plans.

Data availability statement

The data used to support the findings of this study are included within the article.

Author contributions

Y-HJ has made substantial contributions to conception, design, acquisition of data, and writing the original draft. J-BP contributed to analysis and interpretation of data. AK and K-CC contributed

to supervision, review, and editing. 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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Physical activity's impact on rural older adult health: The multiple mediating effects of education, income, and psychological capital

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Introduction: This study aims to explore the influence mechanism of rural older adult health. By examining the mediating roles of education, income, and psychological capital in physical activity's impact on health, this study provides a reference for lifestyle interventions to improve the health level of rural older adults.

Methods: The analysis was conducted on a sample of 1778 rural older adults from CGSS2017, and data were analyzed using PROCESS V4.2 for multiple mediating effects.

Results: The findings indicate that physical activity impacts rural older adult health through multiple mediating pathways. The mediating role includes seven paths, comprising the independent effects of three mediating variables of income, education, and psychological capital, and the chain mediating effects generated together.

Discussion: Based on the influence mechanism of health on rural older adults, optimizing policy focus and developing a precise, interconnected, and sustainable health security system for older adults is necessary. These research results are of practical significance for advancing healthy aging in rural areas.

KEYWORDS

physical activity, older rural adults, psychological capital, multiple mediating, health

1. Introduction

Public health issues have become increasingly important to society, with health level a crucial measure of success (1, 2). Age and group disparities exist in health status, with older adults being particularly vulnerable (3). Health status is a significant factor that influences the life quality of older adults (4). Healthy aging is essential for economic and social development and is the foundation for formulating various social public policies (5). While life expectancy is increasing, the period of illness is disproportionately expanding (6), and chronic diseases in older adults are a significant health concern (7). Older adults require health care and nursing services, with rural older adults particularly needing attention (8, 9).

The issue of rural aging is a major global challenge (10). The diversity of rural areas is an essential consideration in rural aging (11), where, health risk factors and social and economic factors can influence healthy aging in rural areas (12). Changes in the economic structure have reduced rural families' dependence on the land. In contrast, changes in intergenerational relationships have led to declining traditional values and a lack of appropriate social security systems for rural older adults (13). As a result, rural older adults are a particularly fragile group (14) with high levels of disability (15) and caregiving challenges (16), and about one-third of rural older adults experience depressive

symptoms (17). Rural older adults are also at risk of social isolation (18), experiencing social disconnectedness (19). In the context of population aging, exploring the mechanism of health influence on rural older adults can provide for policymaking to improve their health level.

Health is the ability to adapt and self-manage, encompassing physical and mental health (20). It is an essential capability, and all individual activities are based on it (21). Health has personal and public attributes and is the foundation for accumulating human capital (22). Health status results from continuous accumulation throughout life and will decline with age (23). The incidence of health problems varies at different life cycle stages (24). Relative economic backwardness, inadequate medical resources, and lagging health security systems in rural areas have resulted in a long-term accumulation of health disadvantages for older rural adults throughout their lifecycles (25). As a vulnerable group, they are more likely to encounter health risks (26). Cancer incidence and mortality rates among rural residents are higher than those in urban areas (27), and improving the health of older rural adults is vital to healthy aging (28).

Lifestyle, personal, and social factors impact the health of older rural adults (17, 18). Previous research has shown that regarding lifestyle, physical activity, social interaction (29), and diet (30) affect the health of older rural adults. Regarding personal factors, gender (31), income (32), education (33), and marital status (34) all affect the health of older rural adults. Living arrangements are a personal choice for older rural adults (35). They prefer to stay at home and in the community (36), with aging in place (37). Spouses can provide daily care and emotional support (34), and living arrangements and support from children can affect the health of older rural adults (38). Regarding social factors, healthcare needs in rural areas are not being met (39), and healthcare practices affect the health of older rural adults (40, 41). Community resources, infrastructure (42), internet use, and the digital divide (43) affect depression levels in older rural adults. Environmental factors (44) and pollution (45) also affect the health of older rural adults. Health influencing factors result from the interaction and accumulation of multiple factors, which can affect sustainable livelihoods and improve the quality of life for older rural adults (46). Therefore, this study aims to investigate the specific mechanism of rural older adult health.

2. Literature review

Physical activity significantly impacts health (47, 48). It is part of a healthy lifestyle (49, 50), and WHO believes physical activity can improve all aspects of health and provide multiple benefits (51). Physical activity effectively augments health beyond pharmaceutical treatments, lowering disease incidence, improving quality of life, and increasing healthy lifespan (52, 53). Sedentary behavior is a risk factor for older adult health (54) and contributes to overall mortality risk (55). Increasing physical *activity* is an essential strategy for preventing chronic disease (56) and can reverse its effects (57). A linear relationship exists between physical activity and health status (58). Physical activity is a health-promoting behavior (59). Lack of exercise leads to health risks (60, 61). Appropriate physical activity can improve health levels and reduce disability risk in older adults (15, 62), helping to alleviate the trend of disability in older adults (63). Physical activity can prevent frailty (64), delay the development of frailty (65), relieve depression, reduce anxiety, and improve mental health. These outcomes have been observed in residents of different countries (66, 67). Moreover, physical activity strengthens older adults' cognitive function (68). It is a low-cost and effective cognitive function intervention (47, 69). Previous literature has established the impact of physical activity on health. This study primarily concerns how physical activity affects older rural adult health.

Education affects health, providing positive returns on investment (70). The theory of acquired effectiveness states that education is the most critical factor affecting individual health. It endows individuals with various resources, enhancing their sense of control over life and promoting a healthy lifestyle (71). Education and health are both human capital and are mutually reinforcing (72). According to the cumulative advantage and disadvantage hypothesis, the advantages of factors such as education will gradually strengthen. Health differences will continue to expand as health results from accumulated social capital and experience (73). Acceptance and decisions of health risks by older rural adults relate to their level of education, and the level of education has a significant positive effect on the health of older rural adults (33).

Income affects health (74). It is a core indicator of social and economic status, with higher income leading to more robust investment in health capabilities. Income inequality is the main factor of population health differences, and increasing the income of vulnerable groups can reduce health inequality and improve health levels (75). In rural areas, family pension functions are magnified, following the labor lifestyle of living and working into old age and continuously bringing income to the family (6). The increase in income positively affects health as a family's economic support (76). A significant relationship exists between income inequality and health (77). The pension level of older rural adults is low, and pension affects health (32). Medical expenditure is the primary source of the vulnerability of individual and family economic statuses (24), and poverty has a detrimental effect on the health of older rural adults (78).

Psychological capital (PsyCap) affects health (79). It is a core psychological resource, an individual's positive psychological state, including hope, efficacy, resilience, and optimism (80), with developability (81). As a personal resource, psychological capital affects mental health over time (82). It is related to positive emotions, guiding individuals to produce positive behaviors (83), and psychological capital affects successful aging (84). According to the expansion and construction theory of positive emotions, individuals with high psychological capital have more flexible cognitive and behavioral models. They are more likely to obtain energy from the outside when facing external risks (85). Positive psychological capital can protect individuals' health from harm in adversity (86). Psychological capital can improve health levels and alleviate depression in older rural adults (79, 87).

Health is a complex and comprehensive issue that requires a comprehensive measurement approach. Healthy aging emphasizes the centrality of functional ability, which encompasses personal

capabilities, environmental features, and their combination (5). In the functional-centered healthy aging paradigm, physical activity and psychological capital reflect personal capabilities, while education and income are environmental features (88). Previous studies have identified physical activity, income, education, and psychological capital as predictors of health. However, how these variables interact with each other to influence health has not been thoroughly analyzed, and the underlying mechanisms are unclear.

Based on the findings of the studies described above concerning possible predictors of the health of older rural adults, this study examines the following hypotheses:

Hypothesis 1: Education plays a mediating role in the relationship between physical activity and health.
Hypothesis 2: Income plays a mediating role in the relationship between physical activity and health.
Hypothesis 3: Psychological capital plays a mediating role in the relationship between physical activity and health.
Hypothesis 4: Education, income, and psychological capital have multiple mediating effects between physical activity and health.

This study uses income, education, and psychological capital as mediating variables to construct a multiple mediating effect model and test physical activity pathways affecting the health of older rural adults.

3. Methods

3.1. Data sources

This study utilized data from the 2017 China General Social Survey (CGSS), a publicly available data source collecting data at multiple levels, including individuals, households, communities, and society, since 2003. The CGSS is widely used to study social issues due to its high data quality (89), strong applicability, and representativeness (90). After cleaning the original data, urban residents were excluded, followed by individuals below 60, resulting in a sample of older rural adults 60 and above. After removing missing and invalid samples, 1,778 valid samples were obtained, covering 26 provinces and cities in China and comprising 920 males and 858 females. The data contains comprehensive information on the individual characteristics and family situations of older adult respondents, providing robust data support for studying the relationship between physical activity and the health of older rural adults.

3.2. Measurements

The dependent variable was health, measured by physical and mental health (1). The question "How do you feel about your current physical health?" (70) assessed physical health. The re-coded question "How often do you feel depressed or discouraged?" (90) assessed mental health, with higher scores indicating better health. The independent variable was physical activity, measured by the question, "In the past year, do you often participate in physical activity during your leisure time?" (91). Answers were re-coded as *never* or *rarely* (0) and *daily* or *several times a week* (1).

Education, income, and psychological capital were the mediating variables. Education was measured by educational attainment (70). Income was measured by household economic status (91, 92). Psychological capital has four primary positive psychological resources, assessed by the indicators in the survey questionnaire (80, 93).

The hope dimension was measured by the questions "When things are uncertain, I usually expect things to turn out for the best" and "Overall, I expect more good things to happen to me than bad things." The efficacy dimension was measured by "I think I am quite successful now." The resilience dimension was measured by the questions "I am currently doing my best to pursue my goals" and "There are many solutions to the problems I am facing now." Finally, the optimism dimension was measured by the questions "I have a positive attitude toward my future" and "I often get upset about small things." After re-coding the reverse questions and summing up the scores, the higher the composite variable, the better the psychological capital. The four-dimensional psychological capital evaluation index had a Cronbach's α of 0.719, indicating a high level of reliability.

Based on previous studies, control variables included gender (31), marital status (34), and living arrangements (16, 94), all of which were represented as dummy variables.

3.3. Statistical analysis

Data were analyzed using PROCESS V4.2 for multiple mediating effects, which improved the accuracy of the estimation compared to the ordinary mediating effect model (95). The mediating effects were tested using the bootstrap method with 5,000 repeated sampling.

4. Results

4.1. Descriptive statistics and correlation analysis

The descriptive statistics and correlation analysis results of the study variables are shown in Table 1. The Spearman correlation coefficient revealed that physical activity, education, income, and psychological capital were significantly positively correlated with health.

4.2. Regression analysis

The results of the regression are presented in Table 2. Physical activity significantly positively predicted education ($\beta = 0.244$, $p < 0.05$), income (β =0.369, $p < 0.01$), and PsyCap ($\beta = 0.354$, $p < 0.01$). When physical activity, education, income, and PsyCap were entered into the regression equation simultaneously, physical activity ($\beta = 0.216$, $p < 0.05$), education ($\beta = 0.118$, $p < 0.01$), income ($\beta = 0.148$, $p < 0.01$), and PsyCap ($\beta = 0.331$, $p < 0.01$) significantly predicted the health of older rural adults.

TABLE 1 Correlation matrix of main variables.

	M	SD	1	2	3	4	5
1 Physical activity	0.22	0.41	–				
2 Education	1.91	0.86	0.166**	–			
3 Income	2.28	0.80	0.183**	0.183**	–		
4 PsyCap	25.99	5.54	0.205**	0.267**	0.301**	–	
5 Health	6.22	1.78	0.150**	0.215**	0.302**	0.426**	–

**P < 0.01.

TABLE 2 Regression analysis among variables.

Regression equation		Overall Model Fit			Significance	
Outcome variable	Predictor variable	*R*	R^2	*F*	β	*t*
Education	Physical activity	0.394	0.155	22.367**	0.244	2.367*
Income	Physical activity	0.227	0.051	5.276**	0.369	3.354**
	Education				0.141	2.928**
PsyCap	Physical activity	0.384	0.148	13.987**	0.354	3.352**
	Education				0.163	3.542**
	Income				0.225	5.217**
Health	Physical activity	0.482	0.232	20.887**	0.216	2.128*
	Education				0.118	2.670**
	Income				0.148	3.525**
	PsyCap				0.331	7.677**

*P < 0.05, **P < 0.01.

4.3. Mechanism analysis

Physical activity significantly predicted health ($\beta = 0.465$, $p < 0.01$). A chained mediating effect test was conducted using PROCESS, with older rural adults' health as the dependent variable and physical activity as the independent variable, incorporating mediating and control variables. Figure 1 depicts the results. Education, income, and psychological capital play a chained mediating role between physical activity and health.

Table 3 shows the confidence intervals of the indirect effects, found to be statistically significant using the Bootstrap method. Enhancing physical activity, education, income, and psychological capital can effectively improve the health level of older rural adults. The results indicated that the indirect effect was 0.029 in path 1 with education as the mediator, 0.055 in path 2 with income as the mediator, 0.117 in path 3 with psychological capital as the mediator, 0.005 in path 4 with education and income as the mediators, 0.013 in path 5 with education and psychological capital as the mediators, 0.027 in path 6 with income and psychological capital as the mediators, and 0.003 in path with education, income, and psychological capital as the mediators. Hypotheses 1, 2, and 3 have been confirmed.

The mediating effect test results demonstrated that physical activity influences health through multiple mediations of education, income, and psychological capital. Therefore, Hypothesis 4 has also been validated. With a total mediating effect of 0.249, they account for 53.55% of the total effect of physical activity on the health of older rural adults.

5. Discussion

Enhancing the health level of older rural adults requires identifying the mechanism of influence. Research findings indicate that education, income, and psychological capital are the mechanisms by which physical activity impacts the health of older rural adults. Physical activity can improve overall health in older adults and has significant benefits (96). Moreover, physical activity is positively related to and is critical in achieving healthy aging (97). It can be initiated from an early life cycle stage, with robust plasticity, lower cost, and more significant benefit in intervening against and preventing health risks. Intervening with physical activity for older adults is a cost-effective way to improve their health (98). Enhancing physical fitness can lead to lifelong health benefits, enhance the quality of life of older rural adults, and result in sustained health benefits (48, 99, 100).

5.1. Independent mediating effects

Previous studies have found a relationship between physical activity and education, and education has been linked to health (71, 101). Physical activity and education are forms of cultural capital that positively influence rural resident health (92), thus supporting the findings of a mediating effect study of these variables. While some studies have suggested a link between education and physical activity (102–104), identifying causal relationships requires specific research contexts and a constant

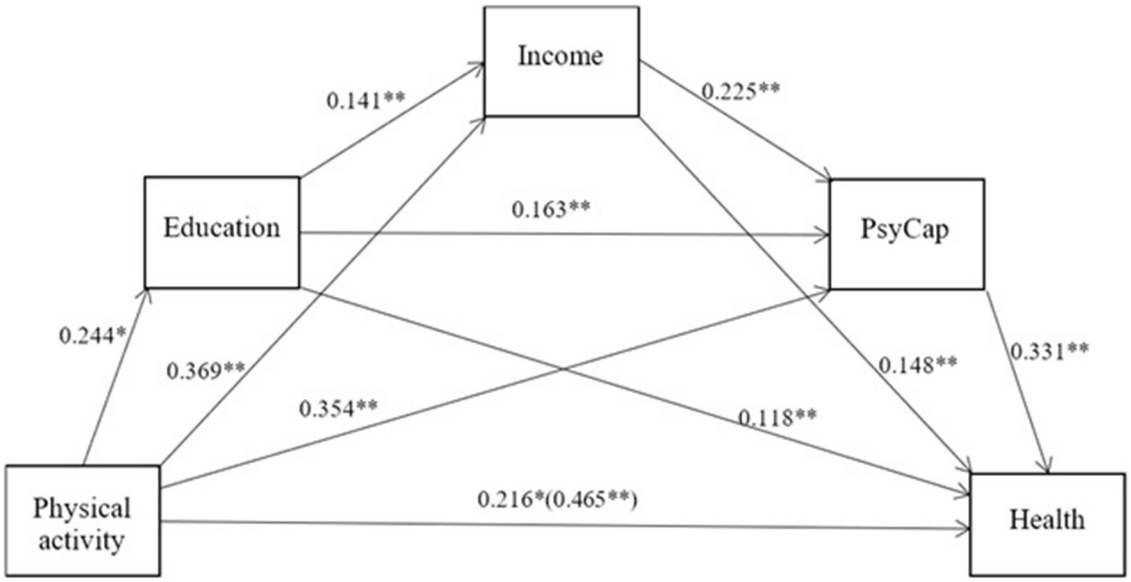

FIGURE 1
Chain mediating model of physical activity, education, income, and PsyCap. $^{*}P < 0.05$, $^{**}P < 0.01$.

TABLE 3 The results of the mediating effect.

	Effect	BootSE	BootLLCI	BootULCI	Relative Effect
Indirect effect	0.249	0.054	0.149	0.361	53.55%
Path 1	0.029	0.018	0.000	0.072	6.24%
Path 2	0.055	0.024	0.017	0.107	11.83%
Path 3	0.117	0.042	0.040	0.208	25.16%
Path 4	0.005	0.004	0.000	0.014	1.08%
Path 5	0.013	0.008	0.001	0.031	2.80%
Path 6	0.027	0.011	0.011	0.052	5.81%
Path 7	0.003	0.002	0.000	0.007	0.65%

conjunction of variables (105). In this study, from a physical activity perspective, education, income, and psychological capital as mediators can help to understand the relationship between physical activity and health (95). In addition, physical activity has been identified as an effective way for individuals to increase their income (91).

Furthermore, physical activity can improve health by enhancing economic status (106). Personal wealth has been found to affect health (107). It has been suggested that the fewer public products and services provided by society, the more significant personal income is to health (108), consistent with the mediating effects of physical activity-income-health. Physical activity has been found to predict psychological capital positively (109). In addition, physical activity may foster and improve psychological capital (81, 110), which is related to health. The theory of planned behavior suggests that behavior beliefs affect attitude formation (111). Older rural adults believe that physical activity will affect health and build psychological capital, consistent with the mediating effects of physical activity-PsyCap-health.

5.2. Multiple mediating effects

Physical activity has been identified as a preventive health behavior (112), which can be explained by the Health Belief Model (113). It has been found that there is a positive correlation between physical activity and educational level (71), as individuals accumulate human capital through education, which can help them to increase their income (114). Income is economic capital that provides access to more health resources (92). Previous studies have shown that physical activity affects education and income (115). Education level and income are two indicators of social and economic status (116), and it has been observed that older adults' health is positively associated with these factors (117). Furthermore, research has shown that education affects health through income (118), which aligns with the mediating effects of physical activity-education-income-health.

Physical activity is linked to educational level. Individuals having higher educational levels exhibit a better social mentality, higher cognitive level, and more optimistic attitudes (71, 101). The

Human Capital Theory suggests that education can affect health through psychological resources (119). Education is a dividing line for health. Individuals shape psychological capital through the educational process, which promotes health behavior intentions to reduce risks (120), thus explaining the mediating effect of physical activity-education-PsyCap-health.

Previous studies have demonstrated that physical activity can bring more income to individuals, with an income effect (121, 122), and income can improve social and economic status (91). Physical activity is cultural, and income is economic capital. Moreover, the durable elements of psychological capital constitute social capital (123). All of these forms of capital are integrated within individuals, mutually influencing and interacting with each other. Health is human capital, affected by cultural, economic, and social capital (79), consistent with the mediating effects of physical activity-income-PsyCap-health.

The Grossman health demand model can explain the multiple mediating model path constructed. This model postulates that health is a durable capital stock (124) with dual attributes of consumption and investment (22). Individual health stock decreases with age. However, it can be augmented through investment (124). Physical activity and education are considered health investment behaviors. Education influences resources and determines the efficiency of health investment. People with higher educational levels tend to have larger incomes, which can be used to purchase wellness services and invest in health capital. Moreover, education affects livelihood resilience (125), forming positive psychological capital in increasing investment and affecting older rural adults' health. The research results confirm the Grossman model.

5.3. Implications

When confronted with unpredictable future health-related risks (126), developing coping strategies and institutional safeguards to optimize policy focus and ensure the social effectiveness of policies is required (70). In addition, an age-friendly, sustainable health security system for older rural adults should be established to promote healthy aging in rural areas (127).

First, when constructing a multi-dimensional health security system for older rural adults, factors such as education, physical activity, and psychological capital should be considered to bring universal health benefits to older rural adults. Particular attention should be paid to older rural adults with low income, low educational levels, and low psychological capital. In addition, precise identification mechanisms for vulnerable groups should be established to ensure they can enjoy policy benefits.

Second, health education is crucial. Education transmits health concepts and prevention information and actively guides older rural adults to engage in physical activity. It encourages effective health decision-making, cultivating healthy lifestyles and health literacy (128), and reducing risks.

Third, creating public service facilities suitable for physical activity and considering the needs of older adults with an inclusive approach is essential. These facilities will provide quality public services, upgrade educational levels and expand income sources for older adults. Furthermore, they will refine social security systems and bolster the psychological capital of older rural adults.

5.4. Limitations and future research

Compared with previous studies, this paper makes several possible contributions. First, based on verifying the effect of physical activity on health using CGSS data, this paper uses income, education, and psychological capital as transmission paths. It uses mediating effect model to study how physical activity impacts the health of older rural adults. Second, prior literature has largely overlooked psychological capital's role in the association between physical activity and health. This paper employs psychological capital as a mediating factor to investigate the health of older rural adults. Third, by leveraging multiple mediating effects to elucidate the health of older rural adults, seven pathways were identified, thus augmenting the existing empirical research.

The core value of this research lies in investigating the effect of physical activity on the health of older rural adults and the mediating roles of education, income, and psychological capital. However, this study has some limitations. First, the health of older rural adults is affected by numerous factors. A considerable time lag may occur, and the effects are cumulative. Thus, only physical activity's influence on health has been studied, which cannot fully explain the long-term dynamic evolution of older rural adults' health. This area requires further exploration.

Regarding influence mechanisms, only education, income, and psychological capital are discussed, which overlooks other aspects. Future research should explore other mechanisms to supplement this paper's findings. Finally, research on older rural adult health should be expanded. More extensive research will help to balance instrumental and value rationality and benefit older rural adults' health and well-being.

6. Conclusions

Health is a universal desire and necessity for human beings. It serves as significant human capital, promotes individual capability, and is an essential resource for society. This study, from the perspective of income, education, and psychological capital, examines the influence mechanism of physical activity on older rural adult health. The findings suggest that income, education, and psychological capital are mediating variables for physical activity to affect older rural adults' health. Physical activity affects the health of older rural adults through multiple mediating effects of income, education, and psychological capital. This mediation effect includes seven paths, including the independent effect of the mediating variable and the chain mediating effect generated together. In light of the mechanism of health influence on older rural adults, this research optimizes the policy focus and constructs a precise, interconnected, and sustainable health security system. The research results are of practical significance for advancing healthy aging in rural areas.

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://cgss.ruc.edu.cn/index.htm.

Author contributions

YS designed the study, performed the statistical analysis, wrote the first draft, polished the manuscript, and approved the submitted version.

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Conflict of interest

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

Publisher's note

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Impact of community care services on the health of older adults: evidence from China

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Introduction: The rapid growth in the population of older adults has put tremendous pressure on medical and social services in countries including China. Community care services are a feasible solution for promoting healthy aging in developing countries. This study investigated the association between community care services and the health of older adults in China.

Method: Using nationally representative survey data from China, consisting of four waves conducted in 2005, 2008, 2011, and 2014, a balanced panel dataset was constructed using a sample of 4,700 older adults (33.1% aged 80 years or older, 51.0% residing in rural areas, and 48.8% women). We employed linear regression models with time-fixed effects and instrumental variable approaches to estimate the effect of community care services on the health of older adults, as well as the differences in these effects across subgroups.

Results: The results showed that community care services lead to a significant improvement in both the objective and subjective health and wellbeing of older adults. Among the various service offerings, spiritual recreation services led to a significant increase in both objective and subjective health scores, while medical care services significantly improved wellbeing. This suggests a varied effect of subdivided service types. Further evidence suggests that spiritual recreation services have a significant health-enhancing effect on multiple groups of older adults, and the effect of medical care services is more effective for those living in rural areas, women, and those who are older than 80 years (all $p < 0.05$).

Discussion: Few studies have examined the impact of community care services on the health of older adults in developing countries. The findings present important implications for improving the health status of older adults and provide suggestions for establishing a socialized aged care system in China.

KEYWORDS

community care services, health promotion, aging, China, health of older adults

1. Introduction

Organizing care for older adults is a serious challenge in the face of global population aging. Institutional care is not widely available and is unlikely to become widespread because of its high costs in many underdeveloped countries (1, 2). Considering the growing burden of providing care for older adults, many countries have opted to promote independent living in the community (3, 4).

Since China became an aging society in 2000, the population aged 65 and older has reached 200.56 million (14.2% of the total population), while the number of beds in

residential long-term care facilities is only 8.135 million.[1] The rapid growth in the population of older adults has put tremendous pressure on medical and social services. Given the small size of family structures, the traditional family-based elderly care system is no longer sustainable in China (5–8). Similar to other developing countries that are growing old before becoming rich, China is unable to provide sufficient institutional nursing beds for its large elderly population. In this condition, prioritizing family-based community care services is necessary to meet the health needs of the elderly (2, 9), improve their health, and extend their life expectancy (10).

However, currently, there is not enough evidence to determine the impact of community care services on the health of the elderly in developing countries. It is also unclear which types of services are more effective in improving the health of the elderly. This lack of empirical evidence makes it difficult to formulate effective social care policies and determine which services should be given priority with limited resources. Therefore, it is important to evaluate the impact of community care services on the health of the elderly, especially through the examination of different types of services.

2. Literature review

The health of older adults not only refers to their physical health but also more importantly their life satisfaction (11). This is because although the decline of physical organs and physiological functions with age is inevitable, older adults can achieve "healthy aging" through better psychological health. Among many variables that affect the health of older adults, scholars have begun to pay special attention to the old-age care model. One reason is that this factor is important for improving the health of older adults, and the other is that policymakers need to assess the impact of different old-age care services to promote their successful development. Several studies have found a significant relationship between the old-age care model and the health of older adults (12, 13). It is evident that mortality was significantly lower among older adults living with others compared to those living alone (14), and aging in places with economic and residential independence significantly affected the health and subjective wellbeing of older adults (15). It is difficult for older adults to decide whether to move from their home to an alternative care location (16, 17). Achieving aging in place is related to the availability of formal or informal support, including material security, emotional support, and timely treatment (18). This suggests that the key determinants of older adults' healthcare are access to life care, medical support, and spiritual support provided by families or socialized organizations.

The World Health Organization's Action Plan on Aging and Health highlights the importance of delivering home- and community-based care to enable older adults to "age in place" with dignity (19). Community care services allow older adults to age in place while providing support such as life care, medical care, and spiritual recreation (20, 21). Some studies point to the positive health impacts of community care services in developing countries, which are designed to meet basic physical- and higher-level spiritual needs (22–24). Different services have different goals and roles in achieving healthy aging (25). One is to prevent the decline of the physical health of older adults, through things like medical care services, which are key in supporting healthy aging (26, 27). Another is to improve the psychological state of loneliness of older adults by keeping them connected with the community. One such example is the provision of life care services that relieve the stress of family caregivers, which benefit older adults' families and thus contribute to life satisfaction (28, 29).

There is insufficient evidence to determine the impact of community care services on the health of older adults in developing countries. Since China has been carrying out community care services for a relatively short period of time, two main theories related to community home care services and the health of older adults have been formed by the academic community. First, from a positive perspective, community home-based care services are conducive to improving physical health and reducing the risk of chronic diseases (30, 31). Other scholars believe that the life satisfaction and depressive symptoms of older adults in the home-based community care model are better than those in institutional care (32, 33). Second, from the problem perspective, the home-based community care model can provide family and social support, but in practice, it does not achieve the effect of $1 + 1 > 2$ (34). Community services have failed to coordinate with home care due to the unregulated nature of community care services, absence of diverse services, long distances from home, and insufficient quantity. If the external stimulation received by older adults living at home is weakened, this may increase their loneliness and isolation (9).

Existing studies on the relationship between community care services and health in China focus on one aspect of health, treat community care services as a whole ignore the differences in the types within them, or present endogenous issues. This study focuses on answering the following four questions: What is the impact of community care services on the health of older adults in China? What type of service has the greatest impact? How do the effects of these impacts differ among older adults of different ages, residences, and genders? How can policies provide targeted community care services?

This study extends existing research on "community care services and health" in three ways. First, as the existing literature on the relationship between community care services and health often suffers from endogeneity, we developed linear regression models (controlling for time periods and regional fixed effects) and reliable instrumental variables (IV) for the independent variables using an IV model to reduce endogeneity bias and obtained robust and credible estimation results. Second, we extended the connotation of older adults' health in multidimensional terms, using three indicators to represent the health of older adults: objective health, subjective self-rated health, and subjective wellbeing, which is closer to real-life health evaluation. Third, recognizing that the relationship between community care services and older adults' health may be affected by service content, we subdivided the community care services into four types: life care, healthcare, spiritual recreation, and legal advocacy services.

1 Source of data: National Health and Welfare Commission, Department of Aging and Health, "National Aging Development Bulletin 2021" http://www.gov.cn/xinwen/2022-10/26/content_5721786.htm.

The main findings of this study are as follows. First, community care services had a generalized effect on the health and wellbeing of the older adult. Second, spiritual recreation and medical care services had a positive effect on the health of the older adult. Third, medical care services had more obvious effects on the health of the rural population, women, and those that are older than 80 years; and spiritual recreation services had a general health-enhancing effect on the older adult. Fourth, the government's prioritization of spiritual recreation services had good health-enhancing effects and medical care services that are important and inadequate for rural older adults. We suggest that providing targeted and diversified services promote healthy aging.

3. Conceptual framework

The health demand theory (35) suggests that the initial stock of health capital is determined innately, and its depreciation rate will continue to increase with age. Therefore, the stock of health capital among consumers appears to decline; to avoid this, consumers can increase their investment in health capital by purchasing medical and other services. Thus, as consumers age, the health depreciation rate increases, and the demand for health services increases. The health production function proposed by Grossman (35), which treats health as a function of medical care, income level, health behavior, and socioeconomic status, constitutes the basis of the health demand model.

Scholars have extended the Grossman health production function to include health as a function of health services, income level, health behavior, socioeconomic status, and other factors (36–38). Liu et al. (15) expanded this by dividing health services into short-term medical care and long-term care services as inputs for health production. According to the community-based home care model, long-term care services are mainly provided by families and communities (4). This study uses Grossman (35) as a starting point and includes community care services as an input for health production:

$$H = f\left(CS, FS, MC\,,\ Y, H_0, X\right), \tag{1}$$

where H represents the health of the older adult, which is explained by the community care services (CS), family support (FS), income (Y), initial health status (H_0), and other variables (X) that represent the socioeconomic characteristics of the older adult.

4. Materials and methods

4.1. Data

This study used data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), organized by Peking University, and publicly available data from the Peking University Open Research Data Platform. In 1998, the baseline survey randomly selected ∼50% of counties and cities in 22 of China's 31 provinces, covering 85% of China's total population. The study targeted institutionalized and community-living older adults. All centenarians who agreed to participate in the selected areas were enrolled in the study. Additionally, octogenarians and nonagenarians were randomly selected based on gender and place of residence (i.e., living in the same street, village, city, or county) as the centenarians. This matching recruitment method resulted in an over-representation of the oldest old and older men in the baseline. The 1998 and 2000 surveys interviewed only the oldest old but the 2002, 2005, and 2008 surveys interviewed the elderly aged between 65 and 79 years and middle-aged persons between 35 and 64 years as well. In the subsequent survey years, samples were replenished in the areas where samples were lost due to death. In the CLHLS, a weight of age–sex–urban/rural residence in the sample with the distribution of the total population in the sampled 22 provinces was employed to reflect the unique sampling design. The data are highly representative, and a detailed description of the study population has been previously published (39, 40).

The survey mainly covered self-rated health status and quality of life status, mobility, residence patterns, economic sources, medical coverage, health behaviors, and demographic and sociological characteristics of the participants. At the same time, medical school students or local healthcare workers who served as investigators conducted basic health examinations of the older adults to provide the objective health status of the interviewed older adults. Participants were followed up in 2000, 2002, 2005, 2008, 2011, and 2014. The survey of the communities where the older adults lived was added in 2005, including the questionnaire on community care services. All the interviewers were intensively trained before the survey. All procedures involving human subjects/patients were approved by Peking University.

In this study, we selected CLHLS data from 2005, 2008, 2011, and 2014, and after excluding the sample of older adults who chose institutionalized care, aged under 80 years, incomplete health information, and incomplete information on community care services, a total of 4,700 participants from four waves (2005, 2008, 2011, and 2014) were selected to construct a balanced panel dataset. The mean age of the total sample was 77.255 (SD 7.355). There were 2,397 (51%) participants who lived in rural areas, and 2,303 (49%) participants who lived in urban areas. The number of male participants was 2,408 (51.2%), and the number of female participants was 2,292 (48.8%).

4.2. Outcome variables

The health of the older adults studied in this article includes both physical and psychological aspects, and the following three indicators are used as key dependent variables to measure the health of the older adults.

The first is objective health, a variable in which the investigator observes and records the health of the interviewee on a scale ranging between 0 = very bad, 1 = bad, 2 = relatively good, and 3 = very good. This can reflect physiological health status more objectively and avoid measurement bias due to unobservable individual heterogeneity. The second is subjective self-rated health, which is a more credible indicator of physiological health widely used in social sciences (41), measured by the response to the question, "How do you rate your health at present?". The third is subjective wellbeing, which measures mental health status from a

broad perspective (42–44) through the response to the question "How do you rate your life at present?". The subjective indicators were assigned a 5-point scale, ranging from 0 = very bad to 4 = very good.

4.3. Explanatory variables

According to the "Plan for the Construction of the Social Elderly Care Service System (2011–2015)" issued by the General Office of the State Council of China, community care services include aspects such as daily living assistance, rehabilitation care, medical care, psychological comfort, and legal services. We assessed community care services using the question "What kind of social services are available in your community?" with eight specific items in the questionnaire including aspects such as daily care services, health education, social psychological comfort, and legal services. The variable of community care services is a binary variable that is defined as equal to 1 if one or more services are available in the respondents' community and equal to 0 otherwise.

To further investigate the impact of the different types of community services, we classified eight specific items into four types and defined them in terms of binary variables. First, life care services such as "personal daily care services" and "daily shopping"; second, healthcare services such as "home visits" and "health education"; third, spiritual recreation services such as "psychological consulting" and "social and recreation activities"; fourth, legal advocacy services such as "human rights consulting services" and "neighboring relations". The variables are defined as equal to 1 if one or more services are available in the respondents' community and equal to 0 otherwise.

4.4. Covariates

According to Grossman's (35) health production function, the health of older adults is also influenced by family support, income, activities of daily living (ADL), medical status, and lifestyle habits.

We used three indicators for family support as follows: living, financial, and emotional support. Living support is measured by the living pattern of the older adults, equal to 1 if living with adult children, and 0 otherwise. Financial support was measured through the survey question "How much money (including cash and value of materials) did you get last year from your children and their spouses whether they are living with you or not?". This variable is defined as equal to 1 if the amount of support is $\geq$100 yuan and 0 otherwise. Third, emotional support was measured based on answers to the question "Who do you ask for help when you have problems or difficulties?" where a value of 1 was assigned if older adults think of their spouses, children, grandchildren, and their spouses first when they need help and 0 otherwise.

Income status includes pensions and primary means of financial support. First, the variable pensions are counted as 1 if the participants have many pensions (including commercial pension insurance). As there is a large proportion of older adults who do not have stable pensions or pensions that are sufficient to cover living expenses in China, the primary means of financial support are divided into three dummy variables as follows: financial independence = 1, if the primary means of financial support is through their pension or their spouse's pension; financial dependence = 1, if the primary means is through their child or other relatives; and government relief = 1, if the primary means is through government funding.

The binary variable ADL is defined as equal to 1 if there is no difficulty in performing ADL tasks (bathing, dressing, toileting, transferring, urine control, and eating) and equal to 0 if there are ADL limitations.

Medical status was measured using two variables: medical insurance and sick care. Medical insurance was defined as equal to 1 if the participant had any public or commercial medical insurance and 0 otherwise. Sick care was defined as 1 if family members provide care and 0 otherwise.

Health behavior was measured based on the smoking and drinking habits of the participants. Smoking and drinking were dummy variables coded as 1 if the respondent smoked or consumed alcohol. We also controlled for a range of demographic and socioeconomic factors, including age, residence, marital status, gender, education, and region.

4.5. Analysis

A linear regression model with a time-fixed effect was used to estimate the effect of community care services on the health of older adults.

$$H_{ijt} = \beta_0 + \beta_1 CS_{ijt} + \varphi X_{ijt}{}' + \theta W_t + \gamma R_j + \mu_{ijt}, \quad (2)$$

where H_{ijt} denotes the health of older adults i living in region j in year t. CS_{ijt} is the binary variable for whether the older adult's community has care services. X'_{ijt} is a vector of covariates and control variables reflecting family support, medical and income status, ADL, health behavior, and demographic characteristics, which have proven to impact health in the previous Grossman model. W_t and R_j are full sets of year and region dummies, respectively, which account for the time period and regional fixed effects.

As the health status of older adults varies over time, and the health status and the subjective wellbeing of older adults may be influenced by regional factors, such as environmental conditions, socioeconomic factors, cultural norms, and healthcare resources, and these difficult-to-measure potential factors can affect our research findings. A linear regression model controlling for time periods and regional fixed effects allows us to estimate the effect of community care services on the health of older adults while accounting for potential confounding factors due to time periods and regions.

To further investigate the impact of different types of community services, we subdivided the community home care services into four types. The basic specification for the analysis is as follows:

$$H_{ijt} = \beta_0 + \beta_1 LC_{ijt} + \beta_2 MS_{ijt} + \beta_3 SR_{ijt} + \beta_4 LA_{ijt} + \varphi X_{ijt}{}' + \theta W_t + \gamma R_j + \mu_{ijt}, \quad (3)$$

where LC_{ijt} is a community-based life care service; MS_{ijt} is a community-based healthcare service; SR_{ijt} is a community-based spiritual recreation service; and LA_{ijt} is a community-based legal advocacy service.

4.6. Robustness analysis

The relationship between community care services and the health of older adults is difficult to interpret because of omitted variables and the presence of a bidirectional link between the two. To avoid endogeneity bias, we first chose county-level community care services supply quantity (from 0 to 8) and four county-level supply rates (from 0 to 1) of life care, medical care, spiritual recreation, and legal advocacy services as instrumental variables (IVs) to verify the robustness of the results. However, it is difficult to search for IVs, since the data collected by CLHLS were randomly selected based on gender and place of residence. We use the information collected from the participants who live in the same county to calculate the county-level community care services supply quantity and the county-level supply rates of life care, medical care, spiritual recreation, and legal advocacy services. An IV analysis requires instruments that are highly correlated with endogenous variables and have no direct effect on the outcome (i.e., are uncorrelated with the error term). Only a handful of studies have used causal econometric methods to address reciprocal causation. The county-level community care service supply is cluster-level information, and the higher the county-level supply rate, the higher the probability that an individual is supplied and, therefore, has a strong correlation with whether an individual is supplied with community aged care services. At the same time, the supply of community care services at the county level cannot directly affect the individual health of people, thereby satisfying the exogenous condition of the instrumental variable. In this study, the F-statistic was evaluated, and over-identification tests were performed to ensure the validity of the IVs.

Second, an individual FE model was provided to further verify the robustness of the results. These unobserved confounding factors are generally considered stable across observation periods, and their effects come from unobservable factors that are offset by each other when examining the effects of key independent variables on the dependent variable, thus avoiding the influence of potentially unobservable confounding factors.

Third, as the key dependent variables in this study are in the order of connotation, we use an ordered logit model to further corroborate the parameter estimation.

5. Results

5.1. Descriptive statistics

Table 1 reports the summary statistics of the main variables. In the full sample, there were some measured differences between the objective and subjective variables. For example, 13.4% of older adults perceived their health to be poor or very poor, whereas CLHLS investigators observed that only 5.7% of older adults were unhealthy or very unhealthy.

We subgrouped the sample according to the supply of community care services, age, residence, and gender. The results showed that a significantly higher proportion of older adults with community care services were very satisfied with their lives ($p < 0.01$). A significantly lower proportion of older adults (age $\geq$ 80 years) had very good objective health (31.9 vs. 39.3%, $p < 0.01$), and a significantly higher proportion were very happy with their lives (21 vs. 16%, $p < 0.01$). Among the urban older adults, 22.3% were very satisfied with their lives, but this proportion was 13.3% in rural areas ($p < 0.01$). A significantly higher proportion of male older adults had very good objective health and a very happy life compared with female older adults (40.9 vs. 32.5%, $p < 0.01$; 15.2 vs. 11.8%, $p < 0.01$).

We list the community care service supply rates. The older adults responded with a total supply rate of 42.6% for community care services, and subtype supply rates of 7.4, 30.3, 17.0, and 25.8% for life care, medical care, spiritual recreation, and legal advocacy services, respectively. The proportion of rural residents with community care services was significantly lower than that of urban residents (38.8 vs. 46.7%, $p < 0.01$; 0.88 vs. 1.19, $p < 0.01$).

Among other explanatory variables, 30.9% of respondents lived with their children, 85.6% had family financial support, and 95% had emotional support from their families. Nearly half of the oldest older adults lived with their children, a proportion two times as high as that of older adults under 80 years ($p < 0.01$), implying that more care is needed with time. Rural seniors made up a lower proportion of those living with their children ($p < 0.01$) and a higher proportion of those living with their family financial support ($p < 0.01$). A lower proportion of men lived with their children and had financial or emotional support from their families ($p < 0.01$).

5.2. Estimation results for community care services and the health of older adults

Table 2 presents community care services as the independent variable. The estimation results using OLS models with time period and regional fixed effects show that community care services are associated with both objective health (evaluated by others) and the self-rated health and wellbeing of old people, therefore, providing a solid basis for further research. Comparing the impact coefficients, the promotion effect of wellbeing is more effective.

To further investigate which type of service has a greater impact, Table 3 shows our preferred specification using OLS models with time period and regional fixed effects that assume community care services are exogenous and the IV models using county-level quantity and four types of supply rates as instruments for community care services. The results for the OLS models are reported in Panel A, with family support, medical status, income status, initial health, health behavior, and demographic category, controlling for a year- and region-fixed effects. In the OLS models, medical care services were significantly associated with a 0.079 increase in subjective wellbeing scores ($p < 0.05$). Spiritual recreation services were significantly associated with a 0.109 increase in objective health scores, a 0.135 increase in subjective health scores, and a 0.106 increase in subjective wellbeing scores (both $p < 0.01$).

TABLE 1 Summary statistics of main variables.

Variable	Total	No service	With service	Age < 80	Age ≥ 80	Rural	Urban	Male	Female
Sample size	4,700	2,696	2,004	3,143	1,557	2,397	2,303	2,408	2,292
Explained variables									
Objective health									
Very bad	0.005	0.004	0.005	0.005	0.004	0.006	0.003	0.005	0.004
Bad	0.052	0.050	0.054	0.047	0.061**	0.052	0.051	0.037	0.067***
Relative good	0.575	0.576	0.574	0.555	0.617***	0.576	0.574	0.548	0.604***
Very good	0.369	0.370	0.367	0.393	0.319***	0.365	0.372	0.409	0.325***
Subjective health									
Very bad	0.007	0.008	0.005	0.007	0.005	0.005	0.008	0.005	0.008
Bad	0.127	0.125	0.130	0.132	0.118	0.143	0.112***	0.110	0.146***
Common	0.359	0.354	0.366	0.355	0.368	0.347	0.372	0.360	0.359
Good	0.371	0.382	0.356*	0.372	0.369	0.377	0.365	0.373	0.369
Very good	0.136	0.131	0.143	0.134	0.140	0.128	0.143	0.152	0.118***
Subjective wellbeing									
Very bad	0.004	0.006	0.002*	0.005	0.003	0.004	0.004	0.002	0.006*
Bad	0.037	0.046	0.025***	0.042	0.028**	0.041	0.033	0.039	0.034
Common	0.344	0.362	0.320***	0.371	0.290***	0.372	0.316***	0.341	0.349
Good	0.438	0.436	0.440	0.422	0.469***	0.450	0.425	0.439	0.436
Very good	0.177	0.150	0.213***	0.160	0.210***	0.133	0.223***	0.178	0.175
Explanatory variable									
Community care services	0.426	0.000	1.000	0.396	0.487***	0.388	0.467***	0.431	0.421
Life care	0.074	0.000	0.173***	0.072	0.078	0.075	0.073	0.075	0.072
Medical care	0.303	0.000	0.711***	0.264	0.382***	0.257	0.351***	0.315	0.291*
Spiritual recreation	0.170	0.000	0.399***	0.158	0.193***	0.120	0.222***	0.177	0.162
Legal advocacy	0.258	0.000	0.605***	0.248	0.277**	0.242	0.274***	0.268	0.247
Family support									
Living support	0.309	0.298	0.323*	0.225	0.477***	0.277	0.342***	0.203	0.419***
Family financial support	0.856	0.852	0.862	0.859	0.850	0.896	0.815***	0.834	0.880***
Family emotional support	0.950	0.946	0.955	0.953	0.943	0.950	0.950	0.943	0.956*
Medical status									
Medical insurance	0.703	0.622	0.812***	0.662	0.786***	0.643	0.766***	0.737	0.668***
Sick care	0.717	0.793	0.614***	0.793	0.562***	0.780	0.651***	0.718	0.715
Income status									
Pension	0.348	0.300	0.412***	0.324	0.396***	0.177	0.525***	0.420	0.272***
Financial independence	0.468	0.473	0.462	0.523	0.357***	0.375	0.564***	0.576	0.354***
Financial dependence	0.440	0.455	0.421	0.396	0.531***	0.544	0.332***	0.333	0.553***
Government relief	0.092	0.073	0.117***	0.081	0.112***	0.081	0.103***	0.091	0.092
Initial health									
ADL	0.934	0.950	0.914***	0.963	0.877***	0.954	0.914***	0.946	0.923***
Health behavior									
Smoking	0.245	0.243	0.248	0.268	0.199***	0.277	0.211***	0.417	0.064***

(Continued)

TABLE 1 (Continued)

Variable	Total	No service	With service	Age < 80	Age ≥ 80	Rural	Urban	Male	Female
Sample size	4,700	2,696	2,004	3,143	1,557	2,397	2,303	2,408	2,292
Drinking	0.233	0.235	0.229	0.243	0.211**	0.267	0.197***	0.360	0.099***
Demographic characteristics									
Age	77.254	76.441	78.348***	73.072	85.697***	76.471	78.070***	77.642	76.848***
Gender (men = 0)	0.488	0.492	0.482	0.499	0.464***	0.495	0.480	0.000	1.000
Residence (rural = 0)	0.490	0.455	0.536***	0.463	0.545***	0.000	1.000	0.498	0.482
Education (illiterate = 0)	0.531	0.525	0.539	0.562	0.469***	0.460	0.605***	0.757	0.293***
Marriage (no spouse = 0)	0.559	0.570	0.542*	0.647	0.379***	0.575	0.541**	0.707	0.403***
Region									
Western Region	0.354	0.382	0.316***	0.343	0.377**	0.352	0.356	0.355	0.353
Central Region	0.272	0.274	0.270	0.271	0.274	0.290	0.254***	0.241	0.305***
Eastern Region	0.374	0.344	0.414***	0.386	0.349**	0.359	0.389**	0.404	0.342***
Year of survey									
2005	0.250	0.300	0.183***	0.315	0.118***	0.310	0.188***	0.250	0.250
2008	0.250	0.333	0.139***	0.281	0.187***	0.295	0.204***	0.250	0.250
2011	0.250	0.200	0.317***	0.232	0.286***	0.214	0.287***	0.250	0.250
2014	0.250	0.168	0.361***	0.171	0.408***	0.181	0.321***	0.250	0.250

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

TABLE 2 OLS estimation results for community care services and the health of older adults.

Variables	(1) Objective Health	(2) Subjective Health	(3) Subjective Wellbeing
Community care services	0.035* (0.021)	0.062* (0.033)	0.109*** (0.030)
Family support	Yes	Yes	Yes
Medical status	Yes	Yes	Yes
Income status	Yes	Yes	Yes
Initial health	Yes	Yes	Yes
Health behavior	Yes	Yes	Yes
Demographic characteristics	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	4,700	4,700	4,700

***, **, and * indicate significance level at 1%, 5%, and 10%, respectively. Robust standard errors with a cluster at the individual level are presented in parentheses.

Panel B shows the results of the IV model after taking the county-level community care services supply quantity rate (from 0 to 8) and the life care, medical care, spiritual recreation, and legal advocacy service supply rates (from 0 to 1) as IV. The results show a significant positive correlation between community care services and the health of older adults. Medical care services led to an increase in subjective wellbeing scores; therefore, the coefficient increased from 0.079 to 0.123. Spiritual recreation services led to an increase of 0.090 in objective health scores ($p < 0.05$) and 0.117 in subjective health scores ($p < 0.1$).

The validity of an instrument relies on two conditions: high correlation with the endogenous variable and no direct effects on the outcome, conditional on the endogenous and exogenous variables. We examined the correlation between county-level IV and the four types of services, and the results show that the association is significantly positive, which is due to the higher county-level supply quantity and higher supply rates indicating a higher probability of an individual receiving a service. The values of the first-stage F-statistic 622.083 for IVs are much higher than the value of 10 for weak identification and the critical value of 26.87 for a 10% IV size, indicating that the chosen instruments are not weak. Next, we ran Hansen J's over-identifying test, given the presence of multiple instruments. The tests were not significant ($p > 0.05$), and the Hansen J-statistic failed to reject the null hypothesis of exogenous instruments.

The regression results for other explanatory variables were more consistent in the OLS and IV models and generally consistent with the theoretical model setting. Regarding family support, living with children and emotional support significantly enhanced the health and wellbeing of older adults. We found that the health gain from family support was stronger than that of community care services when comparing the impact coefficients. Thus, community care provides the necessary support for the overall policy direction of home care. For medical care, sick care is more effective than

TABLE 3 Estimation results for different types of community care services and the health of older adults.

	Panel A: OLS			Panel B: IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Objective Health	Subjective Health	Subjective Wellbeing	Objective Health	Subjective Health	Subjective Wellbeing
Life care services	0.044	0.012	0.039	0.028	−0.032	−0.034
	(0.036)	(0.055)	(0.047)	(0.048)	(0.077)	(0.068)
Medical care services	−0.034	−0.027	0.079**	−0.017	−0.005	0.123***
	(0.024)	(0.038)	(0.034)	(0.031)	(0.049)	(0.043)
Spiritual recreation services	0.109***	0.135***	0.106***	0.090**	0.117*	0.033
	(0.026)	(0.042)	(0.034)	(0.038)	(0.060)	(0.051)
Legal advocacy services	−0.014	−0.010	−0.027	−0.038	−0.017	−0.017
	(0.023)	(0.035)	(0.031)	(0.031)	(0.049)	(0.041)
Living support	−0.013	0.020	0.116***	−0.013	0.020	0.116***
	(0.027)	(0.045)	(0.039)	(0.025)	(0.041)	(0.035)
Family financial support	−0.001	−0.017	0.001	−0.000	−0.018	−0.000
	(0.026)	(0.039)	(0.036)	(0.025)	(0.039)	(0.034)
Family emotional support	0.096**	0.192***	0.202***	0.098**	0.192***	0.201***
	(0.045)	(0.069)	(0.066)	(0.044)	(0.066)	(0.064)
Medical insurance	−0.065***	−0.030	0.009	−0.064***	−0.030	0.010
	(0.023)	(0.037)	(0.032)	(0.022)	(0.035)	(0.031)
Sick care	0.025	−0.009	0.228***	0.025	−0.009	0.229***
	(0.047)	(0.082)	(0.074)	(0.047)	(0.082)	(0.076)
Pension	0.027	0.022	0.180***	0.028	0.024	0.185***
	(0.023)	(0.036)	(0.032)	(0.022)	(0.034)	(0.029)
Financial independence (Government relief = 0)	0.077**	0.117**	0.103**	0.077**	0.117**	0.104**
	(0.034)	(0.058)	(0.049)	(0.032)	(0.049)	(0.044)
Financial dependence (Government relief = 0)	0.004	0.054	0.122**	0.003	0.053	0.120***
	(0.032)	(0.056)	(0.047)	(0.031)	(0.050)	(0.044)
ADL	0.292***	0.248***	0.027	0.294***	0.249***	0.030
	(0.043)	(0.061)	(0.050)	(0.041)	(0.058)	(0.047)
Smoking	0.031	0.014	−0.038	0.031	0.014	−0.040
	(0.025)	(0.040)	(0.033)	(0.022)	(0.034)	(0.030)
Drinking	0.105***	0.183***	0.069**	0.105***	0.183***	0.068**
	(0.023)	(0.037)	(0.031)	(0.021)	(0.033)	(0.028)
Age	−0.003*	0.009***	0.010***	−0.003**	0.009***	0.010***
	(0.002)	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)
Residence (rural = 0)	0.022	0.065**	0.059**	0.022	0.064**	0.061**
	(0.020)	(0.031)	(0.026)	(0.019)	(0.029)	(0.025)
Marriage (no spouse = 0)	−0.058**	−0.014	0.082**	−0.058**	−0.014	0.082**
	(0.027)	(0.047)	(0.041)	(0.024)	(0.040)	(0.035)
Gender (male = 0)	−0.054**	−0.053	0.057	−0.053**	−0.052	0.059*
	(0.027)	(0.044)	(0.037)	(0.022)	(0.035)	(0.031)

(Continued)

TABLE 3 (Continued)

Variables	Panel A: OLS			Panel B: IV		
	(1) Objective Health	(2) Subjective Health	(3) Subjective Wellbeing	(4) Objective Health	(5) Subjective Health	(6) Subjective Wellbeing
Education (illiterate = 0)	0.027	−0.040	0.048	0.027	−0.039	0.050*
	(0.023)	(0.039)	(0.033)	(0.019)	(0.031)	(0.027)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,700	4,700	4,700	4,700	4,700	4,700
First stage F-statistic				801.223		
P-value if Hansen J-statistic				0.172	0.528	0.115

***, **, and * indicate significance level at 1%, 5%, and 10%, respectively. Robust standard errors with a cluster at the individual level are presented in parentheses.

TABLE 4 Robustness checks.

Variables	Panel A: Individual FE			Panel B: Ordered Logit		
	(1) Objective Health	(2) Subjective Health	(3) Subjective Wellbeing	(4) Objective Health	(5) Subjective Health	(6) Subjective Wellbeing
Life care services	0.037	0.000	−0.003	0.206	0.016	0.073
	(0.039)	(0.055)	(0.050)	(0.139)	(0.123)	(0.128)
Medical care services	−0.009	0.015	0.060*	−0.111	−0.030	0.197**
	(0.026)	(0.038)	(0.035)	(0.096)	(0.086)	(0.090)
Spiritual recreation services	0.054*	0.056	0.072*	0.353***	0.254***	0.234**
	(0.028)	(0.044)	(0.039)	(0.102)	(0.096)	(0.092)
Legal advocacy services	0.001	0.033	0.033	−0.040	0.013	−0.008
	(0.025)	(0.036)	(0.033)	(0.091)	(0.082)	(0.082)
Family support	Yes	Yes	Yes	Yes	Yes	Yes
Medical status	Yes	Yes	Yes	Yes	Yes	Yes
Income status	Yes	Yes	Yes	Yes	Yes	Yes
Initial health	Yes	Yes	Yes	Yes	Yes	Yes
Health behavior	Yes	Yes	Yes	Yes	Yes	Yes
Demographic characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes			
Observations	4,700	4,700	4,700	4,700	4,700	4,700

***, **, and * indicate significance level at 1%, 5%, and 10%, respectively. Robust standard errors with a cluster at the individual level are presented in parentheses.

health insurance in enhancing the health of older adults. With regard to income, having a pension significantly enhanced the wellbeing of older adults. Furthermore, ADL affects the health of older adults and smoking had no significant effect on the estimation of health behaviors, whereas drinking significantly improved health and life satisfaction. In addition, according to the regression results, men were healthier than women, and the wellbeing indices were significantly lower in rural compared to urban areas, which is generally consistent with the descriptive statistics (Table 1). The results of the IV model show that the objective health scores decrease significantly as age increases, but subjective health and wellbeing in life increase. The analysis of descriptive statistics (Table 1) also shows that the health status of people over 80 years is worse but for the wellbeing index, this is higher.

In summary, the OLS and IV estimates are generally consistent, which suggests that our empirical findings are relatively robust to the specifications that account for other potentially confounding variables.

TABLE 5 Marginal effects of community care services on the health of older adults.

	Very bad	Bad	Relative good	Good	
Panel A: objective health					
Life care services	−0.001	−0.009	−0.030	0.040	
	(0.001)	(0.006)	(0.020)	(0.027)	
Medical care services	0.001	0.005	0.016	−0.021	
	(0.000)	(0.004)	(0.014)	(0.019)	
Spiritual recreation services	−0.002***	−0.016***	−0.051***	0.068***	
	(0.001)	(0.005)	(0.015)	(0.020)	
Legal advocacy services	0.000	0.002	0.006	−0.008	
	(0.000)	(0.004)	(0.013)	(0.017)	
Panel B: subjective HEALTH					
	Very bad	Bad	Common	Good	Very good
Life care services	−0.000	−0.001	−0.002	0.002	0.002
	(0.001)	(0.012)	(0.012)	(0.012)	(0.013)
Medical care services	0.000	0.003	0.003	−0.003	−0.003
	(0.001)	(0.008)	(0.009)	(0.009)	(0.009)
Spiritual recreation services	−0.002**	−0.024***	−0.026***	0.026***	0.026***
	(0.001)	(0.009)	(0.010)	(0.010)	(0.010)
Legal advocacy services	−0.000	−0.001	−0.001	0.001	0.001
	(0.001)	(0.008)	(0.008)	(0.008)	(0.008)
Panel C: subjective wellbeing					
Life care services	−0.000	−0.002	−0.011	0.005	0.009
	(0.001)	(0.004)	(0.020)	(0.009)	(0.016)
Medical care services	−0.001*	−0.007**	−0.031**	0.014**	0.025**
	(0.000)	(0.003)	(0.014)	(0.006)	(0.011)
Spiritual recreation services	−0.001**	−0.008**	−0.037**	0.016**	0.029**
	(0.000)	(0.003)	(0.015)	(0.007)	(0.012)
Legal advocacy services	0.000	0.000	0.001	−0.001	−0.001
	(0.000)	(0.003)	(0.013)	(0.006)	(0.010)

***, **, and * indicate significance level at 1%, 5%, and 10%, respectively. Robust standard errors are presented in parentheses.Control variables include family support characteristics, medical status characteristics, income status characteristics, ADL, health behavior characteristics, demographic characteristics, and year- and region-fixed effects.

5.3. Robustness checks

Our preferred specification, which controls for a time period and regional fixed effects, shows that the two types of community care services are significantly associated with the health of older adults. We found IVs and the results supported the robustness of the OLS model results. However, the consistency of the estimated quantities relies on the exogeneity of the instruments that are difficult to validate. The results of the individual FE models are provided in Table 4 to further verify the robustness of the results. The individual FE models could eliminate unobserved heterogeneity using the estimator in the panel data regression and require no exclusion restrictions for the identification of instruments (45). Table 4 Panel A presents the results from individual FE regression analyses with control variables, where medical care and spiritual recreation services had a positive effect on the health of older adults, and the results for the other explanatory variables were consistent with the OLS and IV models.

As the variable values of objective health, subjective health, and subjective wellbeing in this study are in order of connotation, Panel B in Table 4 reports the results under the use of an ordered logit model to further corroborate the robustness and credibility of the parameter estimation results.

5.4. Marginal effects

To explain the effects of different types of services more directly and specifically, Table 5 supplements the calculation of the marginal effects of the four types of services on the objective and subjective health and subjective wellbeing of older adults.

TABLE 6 Heterogeneous effect by residence.

	Rural			Urban		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Objective Health	Subjective Health	Subjective Wellbeing	Objective Health	Subjective Health	Subjective Wellbeing
Panel A: OLS						
Life care services	0.055	0.020	0.058	0.044	0.005	0.031
	(0.051)	(0.078)	(0.064)	(0.048)	(0.080)	(0.072)
Medical care services	−0.100	−0.023	0.107**	0.019	−0.037	0.050
	(0.035)	(0.055)	(0.047)	(0.032)	(0.052)	(0.048)
Spiritual recreation services	0.130***	0.122*	0.083*	0.074**	0.148***	0.128***
	(0.040)	(0.064)	(0.048)	(0.033)	(0.055)	(0.048)
Legal advocacy services	−0.040	−0.043	−0.050	0.013	0.012	−0.009
	(0.031)	(0.049)	(0.042)	(0.033)	(0.050)	(0.044)
Panel B: IV						
Life care services	0.035	−0.001	−0.032	0.034	−0.075	−0.035
	(0.070)	(0.108)	(0.088)	(0.065)	(0.113)	(0.106)
Medical care services	0.094**	−0.007	0.153**	0.046	−0.018	0.087
	(0.047)	(0.073)	(0.060)	(0.041)	(0.067)	(0.062)
Spiritual recreation services	0.138**	0.091	−0.055	0.011	0.130	0.085
	(0.059)	(0.093)	(0.071)	(0.049)	(0.080)	(0.074)
Legal advocacy services	0.084*	−0.037	−0.016	0.015	−0.011	−0.027
	(0.044)	(0.071)	(0.055)	(0.043)	(0.067)	(0.061)
First stage *F*-statistic	367.392			404.672		
P-value if Hansen *J*-statistic	0.2650	0.8455	0.1418	0.4448	0.2312	0.2794

***, **, and * indicate significance level at 1%, 5%, and 10%, respectively. Robust standard errors are presented in parentheses. Control variables include family support characteristics, medical status characteristics, income status characteristics, ADL, health behavior characteristics, demographic characteristics, and year- and region-fixed effects.

From the objective health section of Panel A in Table 5, the probability of having "very good" objective health increased by 6.8% and the probability of having "relative health," "bad," and "very bad" health decreased by 5.1, 1.6, and 0.2%, respectively, compared to the reference group that received no community care services. When comparing the impact coefficients, the effect of spiritual recreation services on older adults with poor health was smaller, but they were higher for older adults with good health.

The subjective health section of Panel B showed that, compared to the reference group without spiritual recreation services, the probability of having "very bad", "bad", and "common" subjective health decreased by 0.2, 2.4 and 2.6%; the probability of having "good", and "very good" subjective health increased by 2.6 and 2.6%. This shows that, in general agreement with the findings of the objective indicators, the transition from absence to availability of spiritual recreation services has a more average effect on all but the worst health conditions of older adults.

The subjective wellbeing component of Panel C shows that all other factors being equal, the availability of healthcare and spiritual recreation service provision makes older adults 2.5 and 2.9% more likely to feel very happy, while reducing the probability of feeling unhappy and very unhappy, respectively, compared to a reference group with no community care services.

Community-provided home care services have less impact on the older adults with the poorest health scores and require more specialized therapeutic or rehabilitative care for those with very poor health.

5.5. Heterogeneity analysis

There may be urban–rural gender and age differences in the impact of community-based care services on health. Tables 6–8 present the heterogeneity analyses to determine this.

According to the OLS and IV regression results for rural residents, community-provided medical care services significantly improved wellbeing for the rural older adults but were not significant for the urban older adults. Spiritual recreation services significantly improved the objective health of rural older adults, whereas the effect on urban older adults was not significant under IV models. Since it is more inconvenient for rural older adults to visit a doctor, they worry about the high

TABLE 7 Heterogeneous effect by age.

Variables	65 < Age < 80			Age ≥ 80		
	(1) Objective Health	(2) Subjective Health	(3) Subjective Wellbeing	(4) Objective Health	(5) Subjective Health	(6) Subjective Wellbeing
Panel A: OLS						
Life care services	0.040	−0.041	0.045	0.057	0.110	0.041
	(0.044)	(0.067)	(0.062)	(0.064)	(0.091)	(0.068)
Medical care services	−0.070	−0.055	0.065	0.033	0.029	0.103**
	(0.031)	(0.045)	(0.042)	(0.037)	(0.062)	(0.051)
Spiritual recreation services	0.136***	0.136*	0.147***	0.050	0.120*	0.033
	(0.031)	(0.052)	(0.043)	(0.045)	(0.070)	(0.053)
Legal advocacy services	−0.003	0.003	−0.031	−0.032	−0.024	−0.015
	(0.029)	(0.043)	(0.040)	(0.035)	(0.058)	(0.047)
Panel B: IV						
Life care services	0.049	−0.117	−0.021	0.010	0.144	−0.028
	(0.058)	(0.094)	(0.087)	(0.089)	(0.138)	(0.109)
Medical care services	−0.053	−0.035	0.120**	0.048	0.066	0.124*
	(0.040)	(0.062)	(0.057)	(0.050)	(0.080)	(0.067)
Spiritual recreation services	0.115**	0.069	0.038	0.032	0.175*	0.011
	(0.047)	(0.075)	(0.066)	(0.064)	(0.099)	(0.080)
Legal advocacy services	−0.051	0.017	−0.048	−0.015	−0.070	0.042
	(0.040)	(0.061)	(0.052)	(0.050)	(0.083)	(0.067)
First stage *F*-statistic	524.59			236.798		
P-value if Hansen *J*-statistic	0.764	0.410	0.053	0.034	0.8637	0.8868

***, ** and * indicate significance level at 1%, 5%, and 10%, respectively. Robust standard errors are presented in parentheses. Control variables include family support characteristics, medical status characteristics, income status characteristics, ADL, health behavior characteristics, demographic characteristics, and year- and region-fixed effects.

cost of medical care and do not go to the doctor because they are worried about care after illness. The health support effect on rural older adults may be more effective if the community or village can provide treatment and healthcare for common and chronic diseases and arrange health training seminars (46, 47).

Estimates stratified by age groups reported that community services do not affect the objective health of the oldest people, but significantly improve their subjective health and wellbeing. For those under 80 years of age, the gain effect of spiritual recreation services on objective health was more stable across the models.

For the female older adults, the enhancement effect of medical care services on female residents' wellbeing and the enhancement effect of spiritual recreation services on their objective health were stable under OLS and IV models. For the male older adults, the enhancement effect of spiritual recreation services on objective health and wellbeing in life under OLS models was no longer significant under the IV regression. Legal advocacy services had an enhancing effect on male residents' wellbeing in IV models.

In summary, spiritual recreation services had a general advantage on the health of all older adult groups, while medical care services significantly increased the subjective wellbeing of the oldest female older adults living in rural areas, and legal advocacy services could have improved the wellbeing of male older adults.

6. Discussion

Rapid population aging has led China to consider the introduction of community care services as an essential component of a comprehensive social care package. Using nationally representative survey data from China, this study investigates the impact of community care services on the health of older adults. The results from the OLS and IV models show that community care services led to significant health enhancement for older adults. The impact effects are most pronounced in spiritual recreation services and medical care. Further evidence suggests that the health-enhancement effect of spiritual recreation services is more effective for rural areas, men, and older adults under 80 years and that the health-enhancement effect of medical care services is more effective for rural areas, women, and older adults over 80 years. The effect of community care services was not significant for older adults with the poorest health scores but could significantly improve their quality of life and opportunities to enjoy a sense of wellbeing. Our

TABLE 8 Heterogeneous effect by gender.

Variables	Female			Male		
	(1) Objective Health	(2) Subjective Health	(3) Subjective Wellbeing	(4) Objective Health	(5) Subjective Health	(6) Subjective Wellbeing
Panel A: OLS						
Life care services	0.017	−0.108	−0.008	0.062	0.121*	−0.023
	(0.055)	(0.085)	(0.069)	(0.046)	(0.070)	(0.090)
Medical care services	−0.073	−0.023	0.086*	0.002	−0.027	0.070
	(0.035)	(0.054)	(0.050)	(0.034)	(0.053)	(0.057)
Spiritual recreation services	0.123***	0.195***	0.131***	0.090**	0.081	0.120**
	(0.039)	(0.061)	(0.047)	(0.035)	(0.058)	(0.061)
Legal advocacy services	−0.021	−0.027	−0.081	−0.008	0.005	0.020
	(0.033)	(0.052)	(0.044)	(0.032)	(0.047)	(0.056)
Panel B: IV						
Life care services	0.023	−0.095	0.011	0.022	0.045	−0.079
	(0.069)	(0.112)	(0.094)	(0.068)	(0.107)	(0.100)
Medical care services	−0.103	0.040	0.181***	0.065	−0.063	0.058
	(0.043)	(0.069)	(0.061)	(0.045)	(0.070)	(0.061)
Spiritual recreation services	0.114**	0.082	0.047	0.039	0.123	−0.020
	(0.053)	(0.083)	(0.073)	(0.053)	(0.087)	(0.072)
Legal advocacy services	−0.042	−0.070	−0.147*	−0.036	0.044	0.118**
	(0.044)	(0.068)	(0.056)	(0.043)	(0.070)	(0.059)
First stage *F*-statistic	403.073			367.115		
P-value if Hansen *J*-statistic	0.8289	0.8269	0.2598	0.1013	0.1113	0.1730

***, **, and * indicate significance level at 1%, 5%, and 10%, respectively. Robust standard errors are presented in parentheses. Control variables include family support characteristics, medical status characteristics, income status characteristics, ADL, health behavior characteristics, demographic characteristics, and year- and region-fixed effects.

findings extend the previous research on the relationship between community care services and health in developing countries.

The Chinese government has considered community care as a means of maintaining older adults' independence in their homes for as long as possible, and its current aging policy provides a wide range of services to support older adults in terms of extending active aging and improving their quality of life. However, our findings found that, among the various services currently provided in the community, life care-type services did not have a significant effect on the health and wellbeing of older adults. Sociocultural norms may help explain this finding, as older adults often expect adult children to provide for them, which is consistent with the literature that presents a problem-based perspective. The supply rate of life care services is too low, and the current capacity, professionalism, and quality of services do not meet the care needs of older adults (48, 49). Therefore, community care providers need knowledge and skills in physical, psychological, and medical care. Furthermore, policies and the availability of social resources, especially in conjunction with the development of long-term care insurance, are necessary to provide targeted services to help older adults improve their health and wellbeing, which is a meaningful research direction for the future.

Based on the above research findings, we recommend policymakers to take the following targeted policy measures: First, the supply of community-based medical care services and spiritual recreation services should be strengthened, especially in rural areas. This can be achieved by providing more resources and support to primary care organizations or community care centers in rural areas, and by encouraging the organization of spiritual recreation activities that are popular among older adults. Second, the healthcare needs of older women and those over 80 years should be focused on and more convenient and considerate medical care services should be provided. Meanwhile, for older men and those under 80 years, the supply of spiritual recreation services should be enhanced, and more attractive and diverse community entertainment activities should be provided. Finally, more attention should be given to older adults with poor health conditions, more community care services should be provided, and their quality of life and sense of wellbeing should be improved. These policy measures can improve the health of older adults while narrowing the urban–rural health gap and promoting the healthy development of aging.

The study has several limitations. First, we use three outcome variables to measure the health of older adults, the subjective

self-rated health and subjective wellbeing indicators are measures that rely on the self-perception of the participants, which may be influenced by subjective biases and cultural factors. Although we used objectively observed health conditions by medical students as one of the outcomes, these measures may not fully capture the complexity of health status and may not be sufficient to provide a comprehensive assessment of the health of older adults. The potential implications of these biases and factors need future research. Second, due to data limitations, we used the availability of four types of community care services in the older adults' residing communities as the explanatory variables. In the future, further research should be conducted on more types of community care services, their quality, pricing, and usage, focusing on exploring the mechanisms behind the observed impact of community care services on health and identifying the most effective types of community care services for specific subgroups of older adults. Finally, it should be noted that there is the possibility of an endogeneity bias in this research. Finding instrumental variables is difficult. Although we used county-level community care services as instrumental variables, it assumes all older adults living within the same county have equal access to and utilize the same community care services, which may not be the case. Thus, we developed the individual FE models and the ordered logit model to further corroborate the robustness and credibility of the parameter estimation results. While this robustness check does not allow us to completely reject the hypothesis of an endogenous relationship, our results should, therefore, be interpreted with caution and seen as an entry point for more detailed investigation.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: The data underlying the results presented in the study are available from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), organized by Peking University. Anyone can access through application with the Peking University Open Research Data Platform (https://opendata.pku.edu.cn).

Ethics statement

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

Author contributions

WM: conceptualization and validation. WM and ZS: methodology, formal analyses, investigation, writing—original draft preparation, and writing—reviewing and editing. Both authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

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Identification of status quo and association rules for chronic comorbidity among Chinese middle-aged and older adults rural residents

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Background: Chronic comorbidity has become a major challenge in chronic disease prevention and control. This issue is particularly pronounced in rural areas of developing countries, where the prevalence of chronic disease comorbidity is high, especially among middle-aged and older adults populations. However, the health status of middle-aged and older adults individuals in rural areas of China has received inadequate attention. Therefore, it is crucial to investigate the correlation among chronic diseases to establish a reference basis for adjusting health policies aimed at promoting the prevention and management of chronic diseases among middle-aged and older adults individuals.

Methods: This study selected 2,262 middle-aged and older adults residents aged 50years or older in Shangang Village, Jiangsu Province, China, as the study population. To analyze the chronic comorbidity of middle-aged and older adults residents with different characteristics, we used the χ^2 test with SPSS statistical software. Data analysis was conducted using the Apriori algorithm of Python software, set to mine the strong association rules of positive correlation between chronic disease comorbidities of middle-aged and older adults residents.

Results: The prevalence of chronic comorbidity was 56.6%. The chronic disease comorbidity group with the highest prevalence rate was the lumbar osteopenia + hypertension group. There were significant differences in the prevalence of chronic disease comorbidity among middle-aged and older adults residents in terms of gender, BMI, and chronic disease management. The Apriori algorithm was used to screen 15 association rules for the whole population, 11 for genders, and 15 for age groups. According to the order of support, the most common association rules of comorbidity of three chronic diseases were: {lumbar osteopenia}→{hypertension} (support: 29.22%, confidence: 58.44%), {dyslipidemia}→{hypertension} (support: 19.14%, confidence: 65.91%) and {fatty liver}→{hypertension} (support: 17.82%, confidence: 64.17%).

Conclusion: The prevalence of chronic comorbidity among middle-aged and older adults rural residents in China is relatively high. We identified many association rules among chronic diseases, dyslipidemia is mostly the antecedent, and hypertension is primarily the result. In particular, the majority of comorbidity aggregation patterns consisted of hypertension and dyslipidemia. By implementing scientifically-proven prevention and control strategies, the development of healthy aging can be promoted.

KEYWORDS

rural areas, middle-aged and older adults, chronic comorbidity, association rules, chronic disease

1. Introduction

In recent years, chronic non-communicable diseases (hereinafter referred to as chronic diseases), mainly including cardiovascular and cerebrovascular diseases, cancer, chronic respiratory diseases, and diabetes, have become a significant public health problem worldwide. The causes of chronic diseases are complex, and the course of the disease is prolonged. The negative impact on society, families, and individuals cannot be underestimated (1). WHO has predicted that by 2030, the number of deaths caused by chronic diseases in the world will account for 75% of the total deaths (2). In 2019, the number of deaths caused by chronic diseases in China accounted for 88.5% of the total number of deaths (3). Its incidence and prevalence rates showed an upward trend, and the disease burden caused by chronic diseases accounted for about 70% of the total burden (4). Chronic diseases pose severe challenges to people's quality of life (QoL), and it is particularly important to carry out the prevention and treatment of chronic diseases.

Ensuring the physical and mental health of the population hinges on effective prevention and control of chronic diseases. However, addressing chronic comorbidity poses a significant challenge in this regard. Chronic comorbidity refers to an individual's long-term co-occurrence of two or more chronic diseases (5–7). Compared with a single chronic disease, chronic disease comorbidity will worsen and reduce the QoL of the older adults, leading to the decline of patients' physical function, QoL, disease burden, etc. (8), increasing the difficulty of medical workers' diagnosis and management, and consuming more medical resources (9, 10). Chronic diseases' high occurrence and prevalence seriously threaten human well-being and quality of daily life.

However, the chronic comorbidity issue was particularly prominent in rural areas of developing countries due to economic backwardness worldwide. Sakib et al. (11) pointed out that the incidence rate of chronic comorbidity among low-income people was high. Zhang X et al. (12) indicated that chronic disease comorbidity was prevalent in China and India, with median prevalence being 36.1% (IQR 19.6, 48.8) and 28.3% (IQR 8.9, 56.8), and the burden of disease was increasing. Compared with cities, China's rural health service system is not sound enough, medical technology is relatively backward, and the health level of the population is relatively low. Influenced by behavioral risk factors, residents' unhealthy diets, and habits of work and resting with high salt, high fat, and polysaccharide are widespread (13). The number of chronic disease patients in China is still expanding, and the prevention and treatment of chronic diseases are imminent. In addition, with the deepening of global aging, the risk of chronic diseases for middle-aged and older adults people is gradually increasing. This specific population is particularly susceptible to chronic diseases, and as a result, chronic disease comorbidity is more prevalent among them (14–18). To sum up, it is significant to study the status quo of chronic disease comorbidity among middle-aged and older adults people in rural areas of China (19, 20).

Nowadays, more countries pay attention to chronic comorbidity, and scholars from many countries have begun to study the association model and population characteristics of chronic comorbidity relying on diverse methodologies (21, 22). Im et al. (23) used a multivariable regression model to determine the correlation of chronic comorbidity. Shi et al. (24) used the Markov chain to estimate the probability of another situation in the next state after diagnosis and then conducted weighted association rule mining. Held et al. (25) used network analysis, cluster analysis, and association rules to analyze chronic diseases. Association rules have become an increasingly popular approach for analyzing medical data in recent years. By applying association rules to chronic disease comorbidities, it is possible to identify patterns of two or more chronic diseases, thereby shedding light on the relationships and associations between multiple chronic diseases. Few studies have clarified the pattern of chronic comorbidity in China, and there are relatively few relevant studies. Consequently, our team has undertaken this mission and attempted to bridge this gap through a representative area of the status quo of chronic comorbidities and potential comorbidities among middle-aged and older adults residents in rural China.

Collectively, this paper aimed to answer the following two key questions:

i. What is the status quo of chronic comorbidity among middle-aged and older adults people in rural China?
ii. What are the causal association rules between different chronic diseases?

2. Methods

2.1. Data source and indicator determination

This study selected Shangang Village in Jiangsu Province, a well-developed eastern rural area in China, as an example. The data for the study participants were collected from the grassroots medical and health information system of the sample population. The system included the health examination data (name, gender, age, health evaluation, health guidance, physical examination impression, etc.) of all middle-aged and older adults people participating in the basic medical insurance for urban and rural residents in 2020. Select the top five chronic diseases (lumbar osteopenia, hypertension, dyslipidemia, fatty liver, and cholelithiasis) with the highest frequency in the data set, and make statistics and analysis on the prevalence of chronic diseases among the middle-aged and older adults residents and their association rules.

2.2. Judgment criteria

According to the diagnostic criteria for primary osteoporosis recommended by WHO, lumbar osteopenia is defined: *T*-value≥ −1.0 SD is diagnosed as normal bone mass, −2.5 SD <*T*-value <−1.0 SD is the low bone density or bone mass reduction, and *T*-value ≤−2.5 SD is osteoporosis (26, 27). The criteria for hypertension are: mean systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥ 90 mmHg or antihypertensive drugs were taken in recent 2 weeks. Dyslipidemia: including any one of triglyceride, hypercholesterolemia, high-density lipoprotein, low-high-density lipoprotein, and mixed hyperlipidemia. Fatty liver: confirmed as fatty liver by pathological examination of liver tissue and B ultrasonic examination. Cholelithiasis: There is a stable strong echo light mass in the gallbladder, or it moves with the change of body position, or there is a sound shadow behind it (28). Body mass index (BMI): between 18.5 and 24 is normal, below 18.5 is lean, between 24 and 28 is overweight, and above 28 is obese.

2.3. Principle of association rules

The Apriori algorithm was used to mine association rules between chronic diseases in this study. The so-called association rule is an essential data mining technique used to discover the relevant rules between things and reflect the correlation and dependency between things. If there is a certain rule between the values of two or more variables, one of them can be used to predict other variables (29). Among the many effective algorithms in association rule analysis, the Apriori algorithm has the best performance and the widest application. The Apriori algorithm is a classical algorithm of prior probability. It uses the prior knowledge of the nature of frequent itemsets, and exhausts all frequent itemsets in the data set through the iterative method of layer-by-layer search, thus mining the potential links of the data. Applying association rules to chronic comorbidity can explore the pattern of chronic comorbidity and obtain the causal relationship among chronic diseases (30, 31).

Support, confidence, and lift are commonly used metrics for association rules. The specific concepts are as follows: Set D as the sample database and set A and B as the classification variables in the database.

$$\text{Support}\left(A \rightarrow B\right) = P\left(A \cap B\right) / P\left(D\right) \quad (1)$$

Support indicates the probability of A and B co-occurring in database D. The higher the support, the higher the possibility of A and B co-occurring, and the more critical the association rule is.

$$\text{Confidence}\left(A \rightarrow B\right) = P\left(B|A\right) = P\left(A,B\right) / P\left(A\right) \quad (2)$$

Confidence refers to the conditional probability that B occurs when A occurs in database D. The higher the confidence level, the higher the confidence level of the association rule.

$$\text{Lift}\left(A \rightarrow B\right) = P\left(B|A\right) / P\left(B\right) \quad (3)$$

Lift indicates that in database D when A occurs, the conditional probability of B occurrence is a multiple of the unconditional probability of B occurrence. A high lifting degree stands for the strong impact of A on B and vice versa, which can further reflect the correlation between these two variables in association rules. When the lifting degree is greater than 1 and higher, the higher the positive correlation between A and B is.

These three standards are indispensable, and the absence of any one indicator may lead to incorrect conclusions. The support, confidence, and lift obtained are, respectively, greater than the association rules with the minimum support, minimum confidence, and minimum lift set by the user, called strong association rules.

2.4. Statistical analysis

In this study, the statistical software SPSS 25.0 was used to conduct statistical analysis on five selected chronic diseases. Gender, age, body mass index (BMI), smoking, drinking, chronic disease management, and other factors were included, and the χ^2 test was used to analyze the difference in chronic disease comorbidity among middle-aged and older adults residents. The test level was $\alpha = 0.05$. In order to analyze the correlation and correlation strength between chronic diseases, the mlxtend package in Python 3.8 software was used for data mining of the Apriori algorithm of association rules. Set the minimum support to 1.00%, the minimum confidence to 50.00%, and the lift to be greater than 1.00.

3. Results

3.1. Basic information of respondents

The middle-aged and older adults residents ≥50 years old in the system were selected as the survey objects, and 2,262 pieces of valid data were collected, excluding incomplete information (as shown in Figure 1). The respondents were 35.5% male and 64.5% female, with an average age of 69 years. According to age, 50~59 years old accounted for 18.2%, 60~69 years old for 32.6%, 70~79 years old for 37.2%, and 80 years old and above accounted for 12.0%. The normal rate of BMI was 49.6%, while the rate of smoking, drinking, and chronic disease management was 14.1%, 14.7%, and 48.1%, respectively. The prevalence rate of chronic diseases among middle-aged and older adults residents was 86.7%, including 56.9% of hypertension, 50.0% of lumbar osteopenia, 29.1% of dyslipidemia, 27.8% of fatty liver, and 9.2% of cholelithiasis.

3.2. Current situation of chronic comorbidity

The survey results showed that there were 1,281 middle-aged and older adults residents with chronic comorbidity diseases, with a prevalence rate of 56.6%. Among them, the comorbidity rate of two chronic diseases was 33.5%, the comorbidity rate of three chronic diseases was 17.2%, the comorbidity rate of four chronic diseases was 5.7%, and the comorbidity rate of five chronic diseases was 0.3%. The top three disease combinations were:

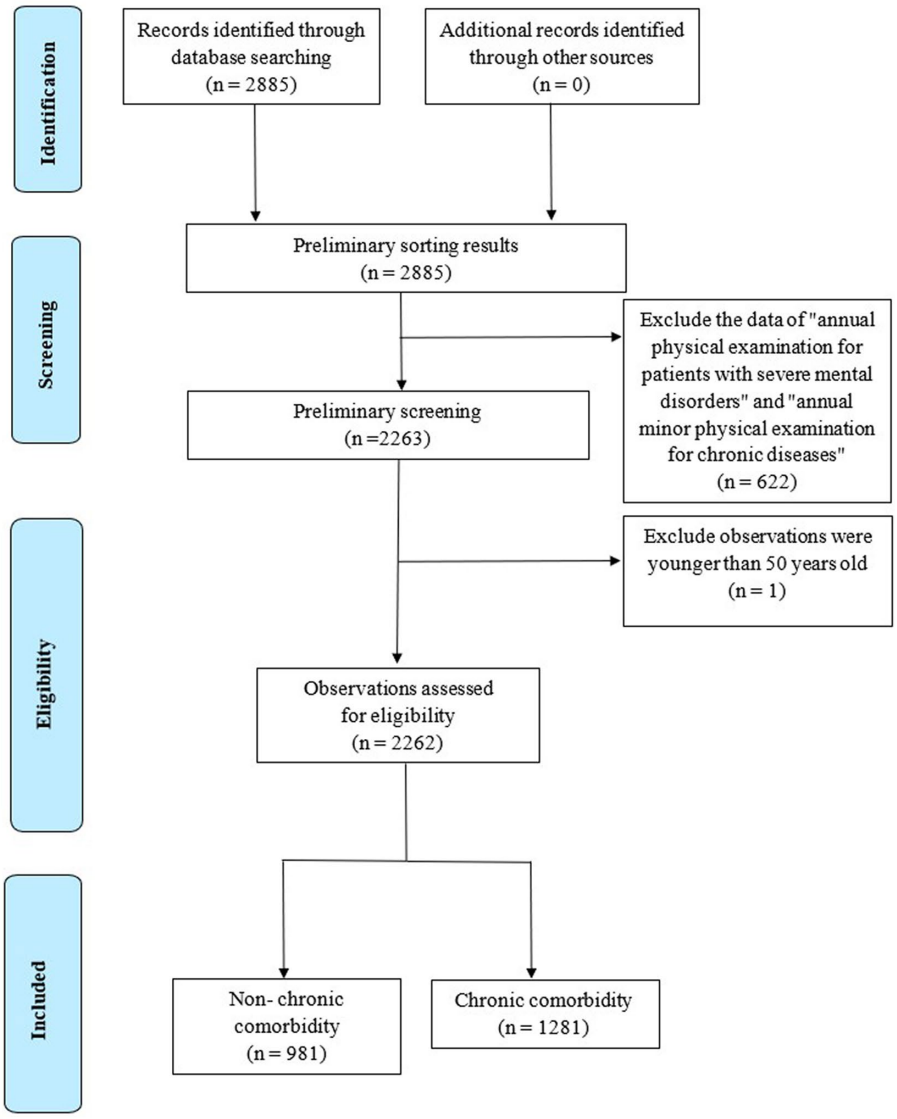

FIGURE 1
PRISMA flow chart of included studies.

1. Lumbar osteopenia + hypertension group (310 persons, 13.7%);
2. Lumbar osteopenia + hypertension + dyslipidemia group (117, 5.2%);
3. Hypertension + dyslipidemia group (106, 4.7%).

The lowest prevalence rate was dyslipidemia + cholelithiasis group (2 persons, 0.1%).

The highest prevalence rate of the dual mode was the lumbar osteopenia reduction + hypertension group, the highest prevalence rate of the ternary mode was the lumbar osteopenia + hypertension + dyslipidemia group, and the highest prevalence rate of the four modes was the lumbar osteopenia + hypertension + fatty liver + dyslipidemia group, as shown in Figure 2.

The distribution of chronic comorbidity among middle-aged and older adults residents in the sample area showed that the comorbidity rate of chronic diseases in women (58.6%) was higher than that in men (53.0%), with a statistically significant difference ($\chi^2 = 6.50$, $p < 0.05$). With the increase in BMI, the overall trend of chronic comorbidity was increasing (the trend χ^2 value is 148.76, $p < 0.05$). The middle-aged and older adults residents with BMI in the obesity range had the highest comorbidity of 2, 3, and 4 chronic diseases. The prevalence of chronic comorbidity of obese residents was about 1.8 times that of normal-weight residents. The comorbidity rate of residents included in chronic disease management (46.4%) was lower than that of residents not included in chronic disease management (66.1%), with a statistically significant difference ($\chi^2 = 88.08$, $p < 0.05$). There was no significant difference in the distribution of chronic comorbidity among age, smoking, and drinking ($p > 0.05$) (as shown in Table 1).

To supplement the quantitative data and further explore the relationship between demographic and sociological characteristics and the prevalence of chronic disease comorbidities among middle-aged and older adults individuals, we randomly selected 40 survey subjects from the database and conducted follow-up interviews. Our

interviews revealed the following: (1) Education status—75% of the respondents had a primary school education or below, and we found no significant relationship between education status and chronic disease comorbidities. (2) Monthly net income situation—45% and 50% of the respondents had a monthly net income of less than 1,000 yuan and between 1,000 yuan and 5,000 yuan, respectively, with very few individuals having a net income between 5,000 yuan and 10,000 yuan. Interestingly, as monthly net income increased, the incidence of chronic comorbidities among respondents decreased. During the interviews, several participants mentioned that they did not seek medical attention for minor illnesses due to financial constraints, resulting in their condition worsening over time. (3) Previous medical history—the interviewees had almost no history of genetic diseases or allergies, and about 25% of them had a history of surgery. However, we found no significant relationship between past medical history and chronic comorbidities (see Figure 3).

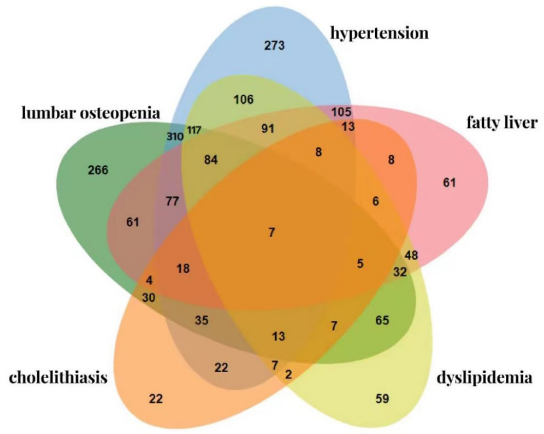

FIGURE 2
Venn diagram of the prevalence of chronic comorbidity in middle-aged and older adults residents.

3.3. Analysis of association rules of chronic comorbidity

The results showed that 15 association rules conform to the above settings, which was the comorbidity mode with strong correlation strength. Among them, there were 6 association rules for binary patterns, 7 association rules for ternary patterns, and 2 association

TABLE 1 Prevalence of chronic comorbidity among middle-aged and older adults residents.

Features	Number of people	Prevalence[a]						Comorbidity[b]	χ^2 value	*p*-value
		0 kind	1 kind	2 kinds	3 kinds	4 kinds	5 kinds			
Gender									6.50	<0.05
Male	803	122 (15.2)	255 (31.8)	250 (31.1)	131 (16.3)	45 (5.6)	0 (0.0)	426 (53.0)		
Female	1,459	178 (12.2)	426 (29.2)	507 (34.7)	258 (17.7)	83 (5.7)	7 (0.5)	855 (58.6)		
Age									3.19	>0.05
50~59	413	51 (12.3)	102 (24.7)	154 (37.3)	78 (18.9)	27 (6.5)	1 (0.3)	260 (63.0)		
60~69	737	97 (13.2)	223 (30.3)	250 (33.9)	127 (17.2)	39 (5.3)	1 (0.1)	417 (56.5)		
70~79	841	121 (14.4)	260 (30.9)	267 (31.7)	144 (17.1)	45 (5.4)	4 (0.5)	460 (54.7)		
80~	271	31 (11.4)	96 (35.4)	86 (31.7)	40 (14.8)	17(6.3)	1(0.4)	144 (53.2)		
BMI									148.76	<0.05
Lean	72	13 (18.1)	28 (38.9)	23 (31.9)	7 (9.7)	0 (0.0)	1 (1.4)	31 (43.0)		
Normal	1,122	208 (18.5)	401 (35.7)	345 (30.8)	144 (12.8)	22 (2.0)	2 (0.2)	513 (45.8)		
Overweight	792	63 (8.0)	216 (27.3)	270 (34.0)	165 (20.8)	75 (9.5)	3 (0.4)	513 (64.7)		
Obese	276	16 (5.8)	36 (13.0)	119 (43.1)	73 (26.5)	31 (11.2)	1 (0.4)	224 (81.2)		
Smoking status									3.39	>0.05
Smoke	318	48 (15.1)	105 (33.0)	98 (30.8)	52 (16.4)	14 (4.4)	1 (0.3)	165 (51.9)		
No smoking	1944	252 (13.0)	576 (29.6)	659 (33.9)	337 (17.3)	114 (5.9)	6 (0.3)	1,116 (57.4)		
Drinking status									0.36	>0.05
Drink	332	40 (12.0)	99 (29.9)	113 (34.1)	61 (18.4)	17 (5.1)	2 (0.6)	193 (58.2)		
No drinking	1930	260 (13.5)	582 (30.2)	644 (33.4)	328 (17.0)	111 (5.6)	5 (0.3)	1,088 (56.3)		
Chronic disease management									88.08	<0.05
Included	1,088	206 (18.9)	377 (34.7)	314 (28.9)	146 (13.4)	44 (4.0)	1 (0.1)	505 (46.4)		
Excluded	1,174	94 (8.0)	304 (25.9)	443 (37.7)	243 (20.7)	84 (7.2)	6 (0.5)	776 (66.1)		

The data outside the a brackets are examples, and the data inside the brackets are composition ratio (%); the data outside the b brackets are the number of people, and the data inside the brackets are the prevalence rate of comorbidity (%).

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rules for quad patterns. Among the 15 association rules, dyslipidemia was the antecedent chronic disease with the highest frequency, and hypertension was the consequent chronic disease with the highest frequency. The latter item only included 2 diseases, including 12 hypertension and 3 lumbar osteopenia (see Figure 3).

The top 3 association rules with the highest support were (as shown in Table 2):

1. {Lumbar osteopenia} → {Hypertension};
2. {Dyslipidemia} → {Hypertension};
3. {Fatty liver} → {Hypertension}.

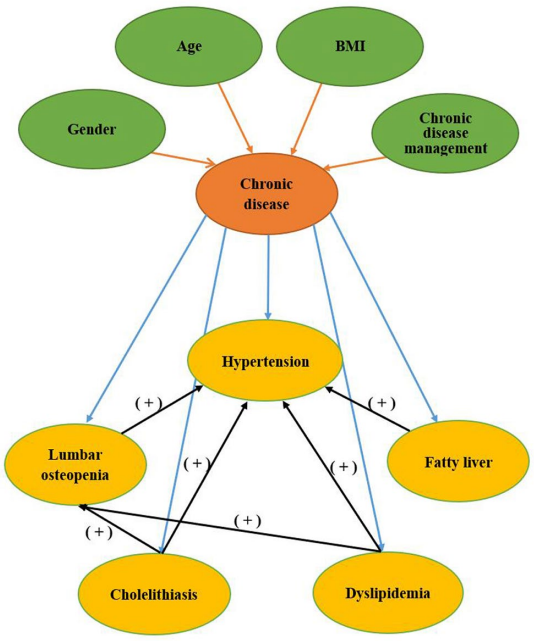

FIGURE 3
The relationship of high-frequency keywords.

The top 3 association rules with the highest confidence and lift were the same, which were:

1. {Cholelithiasis, fatty liver, lumbar osteopenia} → {Hypertension};
2. {Fatty liver, dyslipidemia, lumbar osteopenia} → {Hypertension};
3. {Fatty liver, dyslipidemia} → {hypertension}.

The data were analyzed separately according to gender and age group, and 28 and 52 association rules of comorbidity were obtained, respectively. Due to too many association combinations, we increased the promotion degree to more than 1.19 and obtained 11 gender-related and 15 age-group-related association rules. Among the 11 association rules related to gender, the highest support was {dyslipidemia, lumbar osteopenia} → {hypertension} in men. The highest confidence level and lift were {cholelithiasis, fatty liver, lumbar osteopenia} → {hypertension} of women. The number of association rules for chronic diseases in men was less than in women. In the association rules obtained, the latter term included two chronic diseases, hypertension and lumbar osteopenia, and the incidence of hypertension was high, consistent with the whole population's results. The association rules found in men only include hypertension, which was a chronic disease, while the latter chronic disease in women had a certain reduction in lumbar osteopenia (as shown in Table 3).

Among the 15 association rules related to age group, the latter included 4 diseases involving 9 hypertension, 3 lumbar osteopenia, 2 fatty liver, and 1 dyslipidemia. The highest support was {dyslipidemia} → {fatty liver} in the 50~59 age group. The highest confidence level was {hypertension, cholelithiasis} → {lumbar osteopenia} in the 80~age group. The highest degree of improvement was {fatty liver} → {dyslipidemia} in the 80~age group. Among different age groups, dyslipidemia as the first chronic disease had the

TABLE 2 Analysis of the association of chronic diseases in middle-aged and older adults residents.

Antecedent	Consequent	Support/%	Confidence/%	Lift
Cholelithiasis	Hypertension	5.44	59.42	1.05
Cholelithiasis	Lumbar osteopenia	5.26	57.49	1.15
Dyslipidemia	Lumbar osteopenia	14.59	50.23	1.01
Dyslipidemia	Hypertension	19.14	65.91	1.16
Fatty liver	Hypertension	17.82	64.17	1.13
Lumbar osteopenia	Hypertension	29.22	58.44	1.03
Cholelithiasis, dyslipidemia	Hypertension	1.55	63.64	1.12
Cholelithiasis, dyslipidemia	Lumbar osteopenia	1.41	58.18	1.16
Cholelithiasis, fatty liver	Hypertension	2.03	66.67	1.17
Cholelithiasis, lumbar osteopenia	Hypertension	3.22	61.34	1.08
Dyslipidemia, lumbar osteopenia	Hypertension	9.77	66.97	1.18
Fatty liver, dyslipidemia	Hypertension	8.40	67.62	1.19
Fatty liver, lumbar osteopenia	Hypertension	8.22	64.58	1.14
Cholelithiasis, fatty liver, lumbar osteopenia	Hypertension	1.11	73.53	1.29
Dyslipidemia, fatty liver, lumbar osteopenia	Hypertension	4.02	71.09	1.25

TABLE 3 Analysis on the association of chronic disease comorbidity in different genders.

Gender	Antecedent	Consequent	Support /%	Confidence/%	Lift
Male	Dyslipidemia, lumbar osteopenia	Hypertension	9.96	67.80	1.21
	Fatty liver, dyslipidemia	Hypertension	7.22	68.24	1.22
	Fatty liver, lumbar osteopenia	Hypertension	7.85	67.00	1.20
	Dyslipidemia, fatty liver, lumbar osteopenia	Hypertension	3.74	75.00	1.34
Female	Cholelithiasis	Lumbar osteopenia	6.17	63.38	1.26
	Cholelithiasis, fatty liver	Hypertension	2.12	70.45	1.23
	Cholelithiasis, dyslipidemia	Lumbar osteopenia	1.58	65.71	1.31
	Cholelithiasis, hypertension	Lumbar osteopenia	3.84	65.88	1.31
	Cholelithiasis, dyslipidemia, lumbar osteopenia	Hypertension	1.10	69.57	1.21
	Cholelithiasis, fatty liver, lumbar osteopenia	Hypertension	1.44	80.77	1.41
	Dyslipidemia, fatty liver, lumbar osteopenia	Hypertension	4.18	69.32	1.21

TABLE 4 Analysis of the association of chronic comorbidity in different age groups.

Age	Antecedent	Consequent	Support/%	Confidence/%	Lift
50~59	Dyslipidemia	Fatty liver	15.98	52.80	1.36
	Cholelithiasis, fatty liver	Hypertension	3.15	81.25	1.53
60~69	Dyslipidemia, fatty liver	Hypertension	8.68	69.57	1.20
	Fatty liver, lumbar osteopenia	Hypertension	8.14	69.77	1.20
	Dyslipidemia, fatty liver, lumbar osteopenia	Hypertension	3.80	77.78	1.34
70~79	Cholelithiasis, dyslipidemia	Fatty liver	1.66	53.85	2.20
	Cholelithiasis, dyslipidemia	Hypertension	2.14	69.23	1.20
	Cholelithiasis, dyslipidemia	Lumbar osteopenia	1.90	61.54	1.24
	Dyslipidemia, fatty liver	Hypertension	8.09	70.83	1.23
	Dyslipidemia, lumbar osteopenia	Hypertension	10.58	71.77	1.24
	Dyslipidemia, fatty liver, lumbar osteopenia	Hypertension	3.80	78.05	1.35
80~	Cholelithiasis	Hypertension	5.90	69.57	1.22
	Cholelithiasis	Lumbar osteopenia	7.38	86.96	1.35
	Fatty liver	Dyslipidemia	9.96	51.92	2.47
	Cholelithiasis, hypertension	Lumbar osteopenia	5.17	87.50	1.36

highest frequency, and hypertension as the second chronic disease had the highest frequency, consistent with the population's results. The number of association rules showed an overall upward trend with the increase in age. Only two association rules were found in the 50~59 age group, while six association rules were found in the 70~79 age group. And with the increase of age, the results of chronic disease direction began to diversify (as shown in Table 4).

4. Discussion

To the best of our knowledge, this study is the first time to clarify the status quo of chronic comorbidities among middle-aged and older adults residents in rural areas of China and analyze the association rules between chronic comorbidities. The study found that the prevalence of chronic comorbidity among middle-aged and older adults residents in the sample area was 56.6%. The prevalence rate of chronic disease comorbidity among the older adults in the China Health and Retirement Longitudinal Study (CHARLS) database in 2018 was 57.3 and 63.8% of the older adults in Jiangsu Province (32, 33), but 51.6% higher than that among the middle-aged and older adults in Shanghai and 43.7% in Guangdong Province (34, 35). It is preliminarily estimated that the prevalence rate of chronic comorbidity in the sample areas is about the average level in China, which is representative. Compared with other countries, the comorbidity rate of chronic diseases in the sample area was 80.0% lower than that of people over 65 years old in Australia (36), 64.1% lower than that of adults in Spain (37), between 37.9% and 64.4% of adult comorbidity in the United States (38), higher than that of adults over 55 years old reported in the Netherlands (39), and 16.3% higher than the comorbidity rate reported in Singapore (40). The difference in results might be related to the age of the respondents and the number of chronic diseases included in the study. The age of the subjects was higher, and more types of chronic diseases were included, which might mean a higher prevalence of comorbidities (38, 41). After a comprehensive analysis, we preliminarily judge that the situation of

chronic disease comorbidities in the sample area is relatively serious. According to the field survey, there is a serious shortage of basic-level health human resources in the sample areas. The community health service station has only 3 to 4 medical staff, so the work burden is heavy, and it is difficult to better assume the responsibility of chronic disease management. Simultaneously, the residents lack medical knowledge. There were many unhealthy lifestyles, such as high salt and high oil diet, and poor hygiene habits, which may be the reasons for the high prevalence of chronic diseases in the sample areas. It is suggested that the government should increase the input of medical resources in rural areas, improve the incentive mechanism for medical personnel, and introduce more grassroots talents. We can strengthen the villagers' awareness of health management and help them improve their unhealthy lifestyles by carrying out health lectures and distributing knowledge manuals. The pilot areas should further make full use of the function of prevention and treatment of chronic diseases among primary health institutions and enhance the surveillance and intervention of those diseases among vulnerable groups.

As the various chronic disease comorbidity combinations formed, hypertension and lumbar osteopenia comorbidity combinations among middle-aged and older adults residents are the most common, which was different from the highest incidence rate of cardiovascular disease comorbidity among medical insurance beneficiaries aged 65 and above studied by Nguyen et al. (42) in the United States. This study selected rural residents, while the comparison population was urban community residents. The results obtained may be related to the region's characteristics and the survey object population, such as the poor diet habits of rural older adults residents in the sample area with high salt intake, leading to a high prevalence of hypertension. It may be that the long-term physical labor and lack of adequate nutrient supplements led to the decrease of lumbar osteopenia which become a chronic disease with a high prevalence rate. Based on the results of the status quo among sample areas, the prevalence rate of hypertension was the highest, followed by the prevalence rate of lumbar osteopenia, which should be the focus of prevention and treatment of chronic diseases in this area. It is suggested that the pilot areas should further recognize the pathogenesis, treatment methods, daily prevention, and treatment of these two chronic diseases and take comprehensive multidisciplinary care of patients with chronic diseases to improve the health level of middle-aged and older adults residents.

The results of this study showed that there were significant differences in chronic comorbidity among middle-aged and older adults residents by gender, BMI, and chronic disease management. The prevalence rate of chronic disease comorbidity in the sample area was generally higher in women than in men, the higher the BMI, the higher the comorbidity rate, and the higher the rate of chronic disease not included in chronic disease management than in chronic disease management. The prevalence of chronic comorbidity among women was high, which was consistent with the research results of many scholars in South Korea, Indonesia, and other countries (43–47). This study found through interviews that education and past medical history are not closely related to comorbidities, while economic and other factors may be related to residents' illnesses, which may be influenced by factors such as interview size limitations and sampling bias. The pilot areas should further consider gender differences, especially taking women as a crucial population, combining taking targeted intervention measures to reduce the prevalence of chronic comorbidities. Simultaneously, the pilot areas should pay more attention to the prevalence of chronic comorbidities among overweight or obese middle-aged and older adults residents, strengthen their nutrition, exercise, and other behavioral interventions, and improve the status of overweight and obesity among residents. Furthermore, chronic disease management should include more patients with comorbidities. The governmental department should optimize the health management strategy for chronic diseases and develop corresponding measures for different comorbidity combinations to enhance the health of residents. In order to alleviate the financial strain on patients, it is advisable to enhance the medical insurance system by allocating more resources to the grassroots level through targeted sampling, thereby gradually redirecting the medical insurance fund to where it is needed the most. In future chronic disease prevention and treatment efforts, relevant personnel can categorize the screening population based on gender, BMI, and chronic disease management to improve patient compliance with medical treatment.

The analysis of the Apriori algorithm results of association rules based on the whole population, different genders, and different age groups can draw the following conclusions:

Hypertension might be a multidirectional chronic disease, and dyslipidemia might be associated with hypertension. There may be two reasons for such a result: on the one hand, the association rule algorithm is based on the prevalence rate. The prevalence rate of hypertension among middle-aged and older adults residents in the sample area is higher than that of other chronic diseases, and the results will tend to be a high prevalence of chronic diseases; On the other hand, dyslipidemia and hypertension are cardiovascular diseases with similar risk factors (48). Therefore, if residents have abnormal blood lipids, their blood pressure can be monitored to prevent hypertension.

Compared with men, women were found more association rules and more complex comorbidity. Gender might be one of the risk factors of comorbidity, which was consistent with the results of χ^2 test conducted in this study, as well as with previous studies such as Hernandez et al. (49), Rojas Huerta et al. (50). With the increase of age, women's ovarian function declined, estrogen secretion decreased, and osteoporosis was more likely to occur, which might be the reason for the chronic disease of lumbar osteopenia in the latter item of the association rules related to women (51, 52). Therefore, this once again reminds us that gender differences should be taken into account in the management of chronic comorbidity.

There were some differences in association rules of chronic comorbidity among different age groups. Age is an influencing factor of comorbidity. With the increase of age, the physical function of residents is deteriorating, and the comorbidity of chronic diseases is becoming more complex. It is essential to strengthening the management of comorbidity patterns for the older adults. In addition, the rural economic conditions are poor, the children are mostly employed outside, it is challenging to take care of the older adults at home, and there are many older adults residents left behind. It is suggested that the sample areas should strengthen the health care for the older adults left behind, regularly follow up, distribute basic drugs, etc., to reduce the economic burden of older adults patients with chronic diseases.

In recent years, China has accelerated the implementation of healthy rural construction, implemented the policy of helping the poor and farmers, reformed the rural areas, and greatly improved the economic level. However, there are more middle-aged and older adults

people in rural areas. The quality of medical and health services still needs to be improved, and the health status of the population is relatively poor. There is still a long way to go to improve residents' health. It is suggested that the government should increase the input of medical resources, establish a health service mechanism corresponding to the health of the older adults, improve the prevention and health service system, promote the integration of health and physical education, and improve the health level of the middle-aged and older adults by improving public health services (53).

5. Limitations

This article analyzed the current situation and association rules of chronic comorbidities among middle-aged and older adults people in Jiangsu Province, a well-developed rural area in China. However, the study also had some limitations, as the respondents may not have covered the entire population over 50 years old. Additionally, the information collected on chronic diseases was not very comprehensive, and some data were obtained through diagnostic conclusions. Furthermore, the categories of chronic diseases included were not complete, which could have affected the results. In future studies, more accurate and comprehensive data should be collected to explore the correlation between chronic comorbidities and provide a scientific basis for preventing and treating chronic comorbidities. Scientific prevention and control measures would undoubtedly reduce the harm caused by chronic comorbidity and help promote the development of healthy aging.

6. Conclusion

To sum up, this study found that the overall prevalence of chronic comorbidities among middle-aged and older adults residents in rural China is relatively high, and the situation is relatively tricky. By analyzing the current status of chronic comorbidities, it was found that the prevalence of hypertension and lumbar osteopenia is higher in the sample area. There is a statistically significant difference in the prevalence of chronic comorbidities among middle-aged and older adults residents among different genders, BMI, and chronic disease management methods. Among the association rules formed for chronic diseases, the results of the association rules often point to hypertension. Hypertension and dyslipidemia constitute a majority of comorbidity aggregation patterns, and monitoring the blood pressure status of patients with dyslipidemia has a positive effect on preventing hypertension. In addition, gender and age differences should be given attention in managing chronic disease comorbidities. Improve the health level of middle-aged and older adults people by improving public health services and strengthening the management of chronic disease comorbidities.

Data availability statement

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

Ethics statement

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

Author contributions

ZY: conceptualization, data collection, and writing—original draft preparation. ZY and YC: methodology. ZY and QX: data extraction. ZY and QQ: data analysis. ZY, YC, QX, QQ, and TD: writing—review and editing. TD: supervision, project administration, and funding acquisition. 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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Tooth loss, denture use, and all-cause and cause-specific mortality in older adults: a community cohort study

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Objectives: The available evidence on the connections between tooth loss, denture use, and mortality from all causes or specific causes among older adults is inconclusive. Therefore, we aimed to investigate the association between tooth loss, denture use, and all-cause and cause-specific mortality in older adults.

Methods: A cohort of 5,403 participants aged 65 and older were recruited in the 2014 Chinese Longitudinal Healthy Longevity Survey wave and followed up in the 2018 wave. Cox proportional hazard models were used to examine the association between the number of natural teeth, denture use, and all-cause and cause-specific mortality.

Results: During a mean (SD) follow-up of 3.1 years (1.3), 2,126 deaths (39.3%) occurred. Individuals with 0 and 1–9 teeth had higher mortality due to all-cause, cardiovascular disease (CVD), cancer, and other causes (all p-trend <0.05) than those with 20+ teeth. At the same time, no association was found with respiratory disease mortality. Participants who used dentures had lower mortality due to all causes [hazard ratios (HR) 0.79, 95% confidence intervals (CI) 0.71–0.88], CVD (HR 0.80, 95% CI 0.64–1.00), respiratory disease (HR 0.66, 95% CI 0.48–0.92), and other causes (HR 0.77, 95% CI 0.68–0.88) than those without dentures. Joint analysis revealed that older adults with fewer natural teeth and no dentures had higher mortality. Additionally, interaction analyses showed that the effects of the number of natural teeth on all-cause mortality were more pronounced in older adults aged <80 years (p-value for interaction=0.03).

Conclusion: Having fewer natural teeth, particularly less than 10 teeth, is linked to an increased risk of mortality from all causes, including CVD, cancer, and other causes, but not respiratory disease. The use of dentures would mitigate the adverse impact of tooth loss on all-cause and some cause-specific mortality.

KEYWORDS

dental health, tooth loss, denture use, all-cause and cause-specific mortality, older adults

Introduction

Older adults represent the world's fastest-growing demographic, with the population aged 60 years and up expected to reach 2.1 billion by 2050, up from 900 million in 2015 (1). Unfortunately, aging is associated with a higher likelihood of experiencing chronic diseases, disabilities, social isolation, and other age-related health issues, resulting in increased mortality rates (2). Therefore, understanding the risk factors associated with mortality among older people is vital to develop effective interventions and improve their health and well-being.

Dental health is fundamental to overall health and well-being, particularly in older adults. Natural tooth loss is a crucial factor affecting dental health in older adults. Research has linked tooth loss to several systemic health conditions, including cardiovascular disease (3), respiratory disease (4), diabetes (5), and cancer (6), which may increase the risk of death. The underlying mechanisms may be due to functional limitations (7), poor nutrition (8), and an increase in the total body inflammatory load (9). Despite growing evidence of an association between tooth loss and mortality in older adults, the findings are inconsistent. Some studies have found a strong association between tooth loss and increased mortality (10–14), while others have found no significant association (15–18). Denture use is a standard solution for tooth loss and has been shown to improve chewing ability and dietary intake (19). However, a few population-based studies have focused on the association between tooth loss and denture use and all-cause mortality (14, 20), with no attention to cause-specific mortality. For example, a prospective study found that periodontal disease and tooth loss were linked to elevated all-cause mortality and mortality caused by cardiovascular disease, respiratory disease, and endocrine/metabolic diseases among women aged 35–74 years (10). However, the study only looked at whether or not tooth loss had occurred and did not explore whether the severity of tooth loss or the use of dentures affected mortality. Additionally, only two studies have investigated the potential effect of dietary intake on the number of natural teeth and all-cause mortality (14, 20). Given the potential impact of diet on the relationship between oral health and mortality, it remains unclear whether the findings of previous studies can be extrapolated. Therefore, additional prospective studies of these populations are necessary to clarify the association between tooth loss, denture use, and all-cause and cause-specific mortality.

This study investigates the association between tooth loss, denture use, and all-cause and cause-specific mortality in older adults using data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) and explores their potential interaction. We hypothesize that tooth loss, whether partial or total, is associated with increased all-cause and cause-specific mortality in older adults and that using dentures may mitigate this adverse impact.

Method

Study design and participants

The CLHLS is an ongoing, prospective cohort study investigating the determinants of health and longevity among older Chinese adults. The study includes participants from 22 of China's 31 provinces. The sample was selected using a multistage, stratified cluster sampling method, randomly choosing 631 cities and counties with the largest Han Chinese population. These sample sites represent approximately 85% of the Chinese population (21). The study commenced in 1998, with follow-up interviews conducted every 2–4 years. New participants were enrolled during the follow-up to minimize attrition due to death and loss of follow-up. All included individuals were interviewed face-to-face about determinants of health, including family relationships, socioeconomic characteristics, mental health, physical capacity, chronic disease, and other lifestyle-related measurements. A detailed account of the study design and methods is available (22).

Since the data on cause-specific deaths were only available in the 2018 wave, we used the baseline data from the 2014 wave of CLHLS and conducted a follow-up during the 2018 wave, with a response rate of 79.0%. During the 2014 wave, the study expanded to 23 provinces, adding Chengmai City in Hainan Province (Supplementary Figure S1). The 2014 wave included 7,192 participants. The exclusion criteria in the present study were: age <65 years ($n = 85$), those who were lost to follow-up ($n = 1,511$) or had incorrect death dates ($n = 6$), and missing data on the number of natural teeth and/or denture use ($n = 187$). Finally, 5,403 participants were included to analyze the association between the number of natural teeth, denture use, and all-cause and cause-specific mortality in older adults. A detailed description of the inclusion and exclusion process is shown in Supplementary Figure S2. We compared the baseline characteristics of the overall participants and the included participants in the 2014 wave (Supplementary Table S1). We found that the included participants more likely resided in rural areas, were economically dependent, and reported a lower rate of heart disease.

Exposure assessment

The number of natural teeth was assessed by asking participants about the number of natural teeth they had at baseline. Participants were categorized into four groups based on their number of natural teeth: 0, 1–9, 10–19, and ≥20. Denture use was assessed by asking participants whether they had false teeth at baseline. Participants were categorized into two groups based on their denture use: with dentures and without dentures.

Outcome

The cause of death was determined based on the International Classification of Diseases, 10th Revision (ICD-10) codes. The primary outcome was all-cause mortality. Cause-specific mortality was also examined for the following categories: cardiovascular disease (CVD) (codes I00-I99), respiratory disease (codes J00-99), cancer (codes C00-C97), and other causes. Mortality data were obtained from the participant's next of kin or local doctors. Survival time was calculated from the first interview to the date of death or the last follow-up.

Covariates

We controlled the potential confounding variables associated with the number of natural teeth, denture use, and mortality. These include

age (continuous), sex, education (0 years, 1–6 years, or >6 years), residence (rural area or urban area), marital status [married or other (divorced, widowed, or never married)], living with family members [living with family member(s) or others (living alone or in an institution)], economic status (independence or dependence), smoking (never, current, or former), drinking (never, current, or former), regular exercise (never, current, or former), fruit intake (never, occasionally, or almost daily), vegetable intake (never, occasionally, or almost daily), meat intake (never, occasionally, or almost daily), fish intake (never, occasionally, or almost daily), and egg intake (never, occasionally, or almost daily), body mass index (BMI), chronic complications included self-reported hypertension (yes or no), heart disease (yes or no), diabetes mellitus (yes or no), respiratory disease (including bronchitis, emphysema, pneumonia) (yes or no), and cancer (yes or no). In addition, we classified BMI as underweight (<18.5 kg/m^2), normal (18.5–23.9 kg/m^2), overweight (24–27.9 kg/m^2), and obese (≥28 kg/m^2) (23). Supplementary Figure S3 shows the possible associations between variables.

Statistical analysis

Missing data would reduce statistical power and biased estimates of the relationship. Therefore, we adopted a multiple imputation method based on the chain equation and five repetitions methods to solve the missing data (ranging from 0.2% to 8.3%) (Supplementary Table S2). Baseline characteristics of the study are presented as percentages for categorical variables and mean and standard deviations (SDs) for continuous variables.

Kaplan–Meier survival analysis was utilized to construct survival curves for the number of natural teeth and the denture use, with log-rank testing assessing differences between the groups. Cox proportional hazards models were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for all-cause and cause-specific mortality associated with the number of natural teeth (as a categorical or a continuous variable) and denture use. Model 1 was adjusted for baseline age, sex, residence, living arrangement, economic status, education, and marital status. Model 2 was further adjusted for smoking status, drinking status, regular exercise, fruit intake, vegetable intake, meat intake, fish intake, and egg intake, and further adjusted for denture use in the natural tooth model and further adjusted for the number of natural teeth in the denture use model. Model 3 was further adjusted for BMI, hypertension, heart disease, diabetes mellitus, respiratory disease, and cancer. To examine the individual impacts of tooth loss and denture use on mortality, we adjusted for denture use in the natural tooth model and the number of natural teeth in the denture use model. The crude incidence rate (IR) (per 1,000 person-years) of all-cause and cause-specific mortality was estimated. Linear trend tests were performed using the median values of varying categories of natural teeth numbers as a continuous variable. We used restricted cubic spline curves to examine the association of continuous values of natural teeth (20 natural teeth as reference) with all-cause and specific-cause mortality, with four knots at the 5th, 35th, 65th, and 95th percentiles of change in the natural teeth distribution. We conducted subgroup and interaction analyses by age, gender, denture use, residence, economic status, and BMI to investigate potential effect-modifying effects.

Furthermore, we conducted sensitivity analyses to examine the robustness of our main findings. First, we analyzed complete cases to evaluate the potential effects of the multiple imputation method. Second, to mitigate the potential influence of short-term follow-up, we excluded deaths within the first year, as the impact of oral health on mortality is often a chronic process. Third, we excluded participants with major chronic diseases at baseline, such as heart disease, respiratory disease, and cancer, to minimize some potential reverse causality. Finally, we used inverse probability weighting (IPW) based on the propensity scores to adjust for potential selection bias (24). The weights were the inverse of the probability of follow-up versus loss to follow-up, given the baseline covariates obtained *via* binary logistic regression. To assess the effectiveness of our propensity score modeling, we calculated a standardized mean difference (SMD) (all SMD <0.10).

All analyses were performed using R software version 4.1.3 (R Foundation for Statistical Computing), with a two-tailed $p < 0.05$ as the significance threshold.

Results

Basic characteristics of participants

A total of 5,403 older adults were included. The participants had a mean age of 85.4 years, with 53.8% being female. Table 1 presents the characteristics of the study population. Of all the participants, 80.6% reported having experienced tooth loss, and 35.7% of these individuals had lost all their teeth. The overall rate of denture usage was 35.1%, which increased proportionally with the number of teeth lost. Participants with fewer natural teeth tended to be older, female, unmarried, living alone, residing in rural areas, illiterate, economically dependent, using dentures, and underweight. Moreover, they were less likely to smoke, consume alcohol, exercise regularly, and suffer from hypertension, heart disease, diabetes mellitus, and respiratory diseases. They were likelier to have insufficient vegetables, fruits, meat, and fish intake.

Association of the number of natural teeth with all-cause and cause-specific mortality

Over a median follow-up of 3.4 years (interquartile range: 2.3 to 4.1, 16794.3 person-years), 2,126 (39.3%) participants died, with 435 (20.5%) deaths attributed to CVD, 216 (10.2%) to respiratory diseases, 107 (5.0%) to cancer, and 1,368 (64.3%) to other causes. Kaplan–Meier curves indicate that individuals with fewer teeth have a significantly lower chance of survival (Figure 1). Specifically, participants with 0 teeth had the lowest probability of survival, followed by those with 1–9 teeth, 10–19 teeth, and those with 20 or more natural teeth (log-rank test: $p < 0.001$) (Figure 1).

Individuals with 0 teeth and 1–9 teeth exhibited a substantially higher risk of all-cause mortality (0 teeth: HR 1.66, 95% CI 1.41–1.96; 1–9 teeth: HR 1.43, 95% CI 1.21–1.68) than those with 20+ teeth (Table 2). In addition, cause-specific analyses reveal that individuals with 0 and 1–9 natural teeth had significantly higher mortality from CVD (0 teeth: HR 1.83, 95% CI 1.28–2.63; 1–9 teeth: HR 1.57, 95% CI 1.10–2.24), cancer (0 teeth: HR 2.21, 95% CI 1.13–4.33; 1–9 teeth: HR 2.11, 95% CI 1.13–3.92), and other causes (0 teeth: HR 1.71, 95% CI 1.38–2.12; 1–9 teeth: HR 1.42, 95% CI 1.15–1.76) than those with 20+

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TABLE 1 Characteristics of participants by the number of natural teeth and denture use.

Characteristics	Total (*n* =5,403)	Number of natural teeth					Denture use		
		0 (*n* =1,929)	1–9 (*n* =1,518)	10–19 (*n* =908)	20+ (*n* =1,048)	*p*-value	Yes (*n* =1,896)	No (*n* =3,507)	*p*-value
Age (year), mean (SD)	85.44 (10.47)	89.93 (9.87)	87.00 (9.89)	81.63 (9.07)	78.21 (8.20)	<0.001	83.22 (9.42)	86.64 (10.81)	<0.001
Male, no. (%)	2,496 (46.2)	765 (39.7)	646 (42.6)	466 (51.3)	619 (59.1)	<0.001	942 (49.7)	1,554 (44.3)	<0.001
Married, no. (%)	2,184 (40.4)	537 (27.8)	538 (35.4)	456 (50.2)	653 (62.3)	<0.001	923 (48.7)	1,261 (36.0)	<0.001
Living with family member(s), no. (%)	4,232 (78.3)	1,505 (78.0)	1,150 (75.8)	718 (79.1)	859 (82.0)	0.002	1,501 (79.2)	2,731 (77.9)	0.29
Urban area, no. (%)	2,309 (42.7)	789 (40.9)	630 (41.5)	404 (44.5)	486 (46.4)	0.02	919 (48.5)	1,390 (39.6)	<0.001
Smoking status, no. (%)						<0.001			
Never	3,858 (71.4)	1,437 (74.5)	1,123 (74.0)	628 (69.2)	670 (63.9)		1,287 (67.9)	2,571 (73.3)	<0.001
Current	850 (15.7)	257 (13.3)	226 (14.9)	149 (16.4)	218 (20.8)		332 (17.5)	518 (14.8)	
Former	695 (12.9)	235 (12.2)	169 (11.1)	131 (14.4)	160 (15.3)		277 (14.6)	418 (11.9)	
Drinking status, no. (%)						<0.001			0.04
Never	4,071 (75.3)	1,514 (78.5)	1,163 (76.6)	676 (74.4)	718 (68.5)		1,391 (73.4)	2,680 (76.4)	
Current	807 (14.9)	248 (12.9)	206 (13.6)	141 (15.5)	212 (20.2)		311 (16.4)	496 (14.1)	
Former	525 (9.7)	167 (8.7)	149 (9.8)	91 (10.0)	118 (11.3)		194 (10.2)	331 (9.4)	
Regular exercise, no. (%)						<0.001			<0.001
Never	3,770 (69.8)	1,460 (75.7)	1,075 (70.8)	592 (65.2)	643 (61.4)		1,203 (63.4)	2,567 (73.2)	
Current	1,387 (25.7)	382 (19.8)	359 (23.6)	274 (30.2)	372 (35.5)		610 (32.2)	777 (22.2)	
Former	246 (4.6)	87 (4.5)	84 (5.5)	42 (4.6)	33 (3.1)		83 (4.4)	163 (4.6)	
Education (year), no. (%)						<0.001			<0.001
0	3,103 (57.4)	1,266 (65.6)	972 (64.0)	462 (50.9)	403 (38.5)		914 (48.2)	2,189 (62.4)	
1–6	1,731 (32.0)	522 (27.1)	438 (28.9)	338 (37.2)	433 (41.3)		717 (37.8)	1,014 (28.9)	
>6	569 (10.5)	141 (7.3)	108 (7.1)	108 (11.9)	212 (20.2)		265 (14.0)	304 (8.7)	
Economic independence, no. (%)	1,345 (24.9)	300 (15.6)	317 (20.9)	302 (33.3)	426 (40.6)	<0.001	571 (30.1)	774 (22.1)	<0.001
Number of natural teeth, no. (%)									<0.001
0	NA	NA	NA	NA	NA	NA	1,004 (53.0)	925 (26.4)	
1–9	NA	NA	NA	NA	NA		441 (23.3)	1,077 (30.7)	
10–19	NA	NA	NA	NA	NA		268 (14.1)	640 (18.2)	
20+	NA	NA	NA	NA	NA		183 (9.7)	865 (24.7)	
Denture use, no. (%)	1,896 (35.1)	1,004 (52.0)	441 (29.1)	268 (29.5)	183 (17.5)	<0.001	NA	NA	NA
BMI (kg/m^2), no. (%)						<0.001			<0.001
Underweight (<18.5)	1,048 (19.4)	454 (23.5)	326 (21.5)	141 (15.5)	127 (12.1)		283 (14.9)	765 (21.8)	
Normal (18.5–24)	3,024 (56.0)	1,087 (56.4)	853 (56.2)	531 (58.5)	553 (52.8)		1,085 (57.2)	1,939 (55.3)	
Overweight (24–28)	1,023 (18.9)	302 (15.7)	267 (17.6)	182 (20.0)	272 (26.0)		409 (21.6)	614 (17.5)	
Obese (≥28)	308 (5.7)	86 (4.5)	72 (4.7)	54 (5.9)	96 (9.2)		119 (6.3)	189 (5.4)	
Hypertension, no. (%)	1,758 (32.5)	509 (26.4)	500 (32.9)	342 (37.7)	407 (38.8)	<0.001	653 (34.4)	1,105 (31.5)	0.03
Diabetes mellitus, no. (%)	281 (5.2)	74 (3.8)	65 (4.3)	64 (7.0)	78 (7.4)	<0.001	120 (6.3)	161 (4.6)	0.01
Heart disease, no. (%)	665 (12.3)	185 (9.6)	195 (12.8)	124 (13.7)	161 (15.4)	<0.001	260 (13.7)	405 (11.5)	0.02
Respiratory disease, no. (%)	591 (10.9)	184 (9.5)	187 (12.3)	89 (9.8)	131 (12.5)	0.01	228 (12.0)	363 (10.4)	0.07

(Continued)

TABLE 1 (Continued)

Characteristics	Total (*n* =5,403)	Number of natural teeth					Denture use		
		0 (*n* =1,929)	1–9 (*n* =1,518)	10–19 (*n* =908)	20+ (*n* =1,048)	*p*-value	Yes (*n* =1,896)	No (*n* =3,507)	*p*-value
Cancer, no. (%)	44 (0.8)	13 (0.7)	13 (0.9)	13 (1.4)	5 (0.5)	0.10	20 (1.1)	24 (0.7)	0.20
Fruit intake, no. (%)						<0.001			<0.001
Never	1,360 (25.2)	508 (26.3)	424 (27.9)	201 (22.1)	227 (21.7)		406 (21.4)	954 (27.2)	
Occasionally	1,863 (34.5)	639 (33.1)	549 (36.2)	337 (37.1)	338 (32.3)		597 (31.5)	1,266 (36.1)	
Almost daily	2,180 (40.3)	782 (40.5)	545 (35.9)	370 (40.7)	483 (46.1)		893 (47.1)	1,287 (36.7)	
Vegetables intake, no. (%)						<0.001			<0.001
Never	196 (3.6)	114 (5.9)	55 (3.6)	14 (1.5)	13 (1.2)		51 (2.7)	145 (4.1)	
Occasionally	452 (8.4)	191 (9.9)	148 (9.7)	61 (6.7)	52 (5.0)		125 (6.6)	327 (9.3)	
Almost daily	4,755 (88.0)	1,624 (84.2)	1,315 (86.6)	833 (91.7)	983 (93.8)		1,720 (90.7)	3,035 (86.5)	
Meat intake, no. (%)						<0.001			0.27
Never	365 (6.8)	165 (8.6)	106 (7.0)	41 (4.5)	53 (5.1)		124 (6.5)	241 (6.9)	
Occasionally	2,993 (55.4)	1,025 (53.1)	855 (56.3)	534 (58.8)	579 (55.2)		1,027 (54.2)	1,966 (56.1)	
Almost daily	2,045 (37.8)	739 (38.3)	557 (36.7)	333 (36.7)	416 (39.7)		745 (39.3)	1,300 (37.1)	
Fish intake, no. (%)						<0.001			0.001
Never	915 (16.9)	369 (19.1)	285 (18.8)	140 (15.4)	121 (11.5)		302 (15.9)	613 (17.5)	
Occasionally	4,072 (75.4)	1,424 (73.8)	1,119 (73.7)	684 (75.3)	845 (80.6)		1,415 (74.6)	2,657 (75.8)	
Almost daily	416 (7.7)	136 (7.1)	114 (7.5)	84 (9.3)	82 (7.8)		179 (9.4)	237 (6.8)	
Egg intake, no. (%)						0.10			<0.001
Never	488 (9.0)	182 (9.4)	148 (9.7)	66 (7.3)	92 (8.8)		169 (8.9)	319 (9.1)	
Occasionally	3,310 (61.3)	1,141 (59.1)	928 (61.1)	584 (64.3)	657 (62.7)		1,090 (57.5)	2,220 (63.3)	
Almost daily	1,605 (29.7)	606 (31.4)	442 (29.1)	258 (28.4)	299 (28.5)		637 (33.6)	968 (27.6)	

Values are presented as number (%) or mean ± SD. Differences in characteristics were compared using the χ^2 test for categorical variables and ANOVA or *t*-test for continuous variables. BMI, body mass index.

teeth, but not from respiratory disease (Table 2). Furthermore, the hazard ratios (HRs) for the risk of death for the number of teeth (continuous variable) were as follows: 0.98 (0.97–0.98) for all-cause mortality, 0.98 (0.96–0.99) for cardiovascular disease (CVD) mortality, 0.97 (0.95–0.99) for cancer mortality, and 0.98 (0.97–0.98) for mortality from other causes (Table 2).

Restricted cubic spline analysis shows a linear trend in the correlation between the number of natural teeth and mortality due to all-cause, CVD, respiratory disease, and other causes (Figure 2; Supplementary Figure S4). However, no linear or non-linear relationship was found between the number of natural teeth and cancer mortality (Supplementary Figure S4).

Association of denture use with all-cause and cause-specific mortality

The Kaplan–Meier analyses of denture use indicate that participants with dentures had higher survival than those without (Supplementary Figure S5). In addition, individuals with dentures demonstrated a lower risk of all-cause mortality (HR 0.79, 95% CI 0.71–0.88), CVD mortality (HR 0.80, 95%CI 0.64–1.00), respiratory disease mortality (HR 0.66, 95% CI 0.48–0.92), and mortality attributed to other causes (HR 0.77, 95% CI 0.68–0.88) than those without dentures. However, no significant difference was observed in cancer mortality (Table 2).

Combined association of the number of natural teeth and denture use with all-cause and cause-specific mortality

The Kaplan–Meier survival curves stratified by the number of natural teeth and denture use show that individuals with 0 teeth without dentures exhibited the lowest survival rates, whereas those with 10–19 teeth with dentures had the highest survival rates (Supplementary Figure S6). In addition, individuals with 0 teeth without dentures, 0 teeth with dentures, and 1–9 teeth without dentures had a significantly higher risk of all-cause mortality, CVD mortality, and other cause mortality than those with 20+ teeth with/without dentures (Table 3). Specifically, the HRs for all-cause mortality were 1.71, 1.37, and 1.48. The corresponding HRs for CVD mortality were 1.85, 1.55, and 1.65. The HRs for other causes of mortality were 1.76, 1.38, and 1.45. Moreover, individuals who had 0 teeth without dentures were also at a significantly higher risk of respiratory disease mortality (HR 1.75, 95% CI 1.06–2.87) than those who had 20+ teeth with/without dentures, while those who had 0 teeth with dentures and 1–9 teeth without dentures had a significantly higher risk of cancer mortality (HR 2.27, 95% CI 1.20–4.29 and HR 2.35, 95% CI 1.20–4.57, respectively) (Table 3). In contrast, individuals with 10–19 teeth with/without dentures and 1–9 teeth with dentures were not found to have a significantly high risk of all-cause mortality or cause-specific mortality when compared to those with 20+ teeth with/without dentures (Table 3).

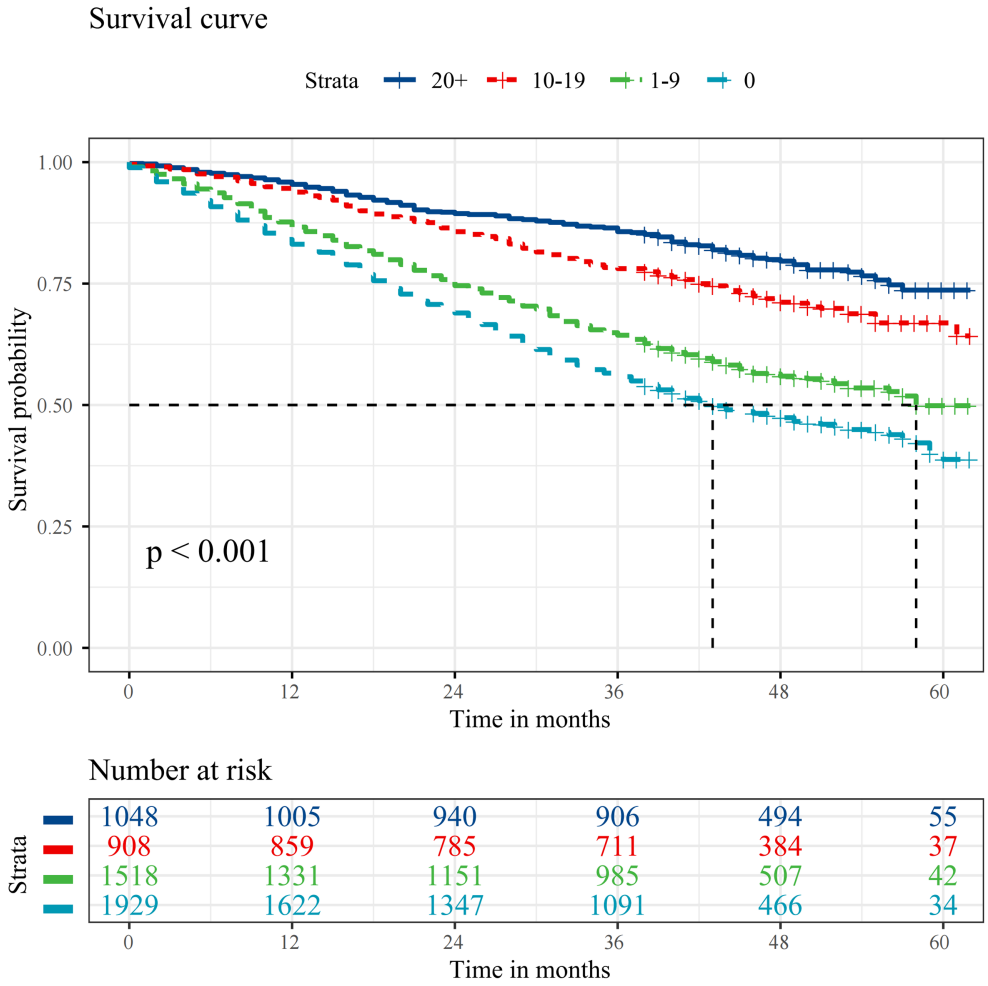

FIGURE 1
Kaplan–Meier survival curves for all-cause mortality according to the number of natural teeth. The median survival duration is represented using a vertical dashed line.

Effect modification

Supplementary Figure S7 reveals that the association between the number of natural teeth and all-cause mortality was more pronounced in older adults aged <80 years (than those aged ≥80 years) (*p*-value for interaction = 0.03). Among individuals aged ≥80 years, only those with fewer than 10 teeth had a higher risk of all-cause mortality. No other variables, including sex, residence, BMI, economic status, and denture use, significantly modified the association between the number of natural teeth and denture use and all-cause and cause-specific mortality (Supplementary Figures S8–12).

Sensitivity analysis

The associations between the number of natural teeth and denture use with all-cause and cause-specific mortality remained consistent after excluding participants with missing covariate values (Supplementary Table S3). Similarly, after removing participants who died within one year of follow-up, no essential changes in the results were observed (Supplementary Table S3). Additionally, no substantive changes in the results were observed when excluding participants with pre-existing conditions such as heart disease, respiratory disease, and cancer (Supplementary Table S3). Finally, after conducting IPW using propensity scores, no substantive differences were observed in the results (Supplementary Table S3).

Discussion

This community-based cohort study in China adds to the existing literature on the association between tooth loss, the use of dentures, and mortality among older adults. Our findings reveal that participants with fewer natural teeth, particularly those with 0 and 1–9 teeth and those without dentures, are at a higher risk for all-cause and cause-specific mortality, particularly for CVD, cancer, and other causes. Moreover, this association persisted after adjusting for potential confounding factors, such as dietary intake, socioeconomic status, and other health behaviors. In addition, among participants without dentures, those with 0 teeth or 1–9 teeth had a higher mortality risk than those with 20+ teeth and with/without dentures. Conversely, dentures appeared to mitigate mortality in participants with partial tooth loss.

TABLE 2 Hazard ratios for all-cause and cause-specific mortality according to the number of natural teeth or denture use.

Characteristic	Number of deaths (incidence rate, per 1,000 person-year, %)	Unadjusted model	Model 1	Model 2	Model 3
		HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Number of natural teeth					
All-cause mortality					
20+	214 (56.7)	Reference	Reference	Reference	Reference
10–19	257 (82.4)	1.45 (1.21–1.74)	1.11 (0.92–1.33)	1.12 (0.93–1.34)	1.11 (0.92–1.34)
1–9	657 (143.4)	2.54 (2.18–2.96)	1.39 (1.19–1.64)	1.43 (1.21–1.68)	1.43 (1.21–1.68)
0	998 (187.6)	3.33 (2.87–3.86)	1.54 (1.32–1.80)	1.65 (1.40–1.95)	1.66 (1.41–1.96)
p-value for trend[a]		<0.001	<0.001	<0.001	<0.001
Number of teeth (continuous variable)		0.95 (0.95–0.96)	0.98 (0.98–0.99)	0.98 (0.97–0.99)	0.98 (0.97–0.98)
Cardiovascular disease mortality					
20+	45 (13.2)	Reference	Reference	Reference	Reference
10–19	60 (22.1)	1.67 (1.13–2.45)	1.23 (0.83–1.82)	1.26 (0.85–1.86)	1.32 (0.89–1.95)
1–9	139 (38.2)	2.86 (2.04–4.00)	1.44 (1.02–2.05)	1.49 (1.04–2.12)	1.57 (1.10–2.24)
0	191 (49.0)	3.64 (2.63–5.04)	1.56 (1.11–2.19)	1.67 (1.16–2.39)	1.83 (1.28–2.63)
p-value for trend[a]		<0.001	0.007	0.004	<0.001
Number of teeth (continuous variable)		0.95 (0.94–0.96)	0.98 (0.97–0.99)	0.98 (0.97–0.99)	0.98 (0.96–0.99)
Respiratory disease mortality					
20+	30 (8.9)	Reference	Reference	Reference	Reference
10–19	33 (12.5)	1.40 (0.85–2.29)	1.07 (0.65–1.77)	1.02 (0.62–1.70)	1.03 (0.62–1.73)
1–9	62 (17.8)	1.99 (1.28–3.07)	1.23 (0.78–1.93)	1.27 (0.80–2.01)	1.25 (0.79–1.99)
0	91 (24.3)	2.70 (1.78–4.07)	1.43 (0.93–2.21)	1.57 (0.99–2.50)	1.67 (0.98–2.65)
p-value for trend[a]		<0.001	0.08	0.04	0.06
Number of teeth (continuous variable)		0.96 (0.95–0.98)	0.99 (0.97–1.00)	0.98 (0.97–1.00)	0.98 (0.96–1.00)
Cancer mortality					
20+	17 (5.1)	Reference	Reference	Reference	Reference
10–19	20 (7.6)	1.50 (0.79–2.87)	1.56 (0.81–3.00)	1.62 (0.83–3.13)	1.55 (0.79–3.04)
1–9	34 (9.9)	1.95 (1.09–3.48)	2.12 (1.16–3.87)	2.11 (1.13–3.91)	2.11 (1.13–3.92)
0	36 (9.8)	1.94 (1.09–3.46)	2.12 (1.15–3.89)	2.11 (1.08–4.11)	2.21 (1.13–4.33)
p-value for trend[a]		0.01	0.007	0.01	0.01
Number of teeth (continuous variable)		0.98 (0.96–1.00)	0.97 (0.95–0.99)	0.97 (0.95–0.99)	0.97 (0.95–0.99)
Other cause mortality					
20+	122 (34.1)	Reference	Reference	Reference	Reference
10–19	144 (49.8)	1.46 (1.15–1.86)	1.03 (0.81–1.31)	1.05 (0.82–1.34)	1.03 (0.81–1.32)
1–9	422 (101.4)	2.98 (2.43–3.64)	1.39 (1.13–1.72)	1.42 (1.15–1.76)	1.42 (1.15–1.76)
0	680 (142.3)	4.17 (3.44–5.06)	1.61 (1.31–1.97)	1.72 (1.39–2.13)	1.71 (1.38–2.12)
p-value for trend[a]		<0.001	<0.001	<0.001	<0.001
Number of teeth (continuous variable)		0.94 (0.93–0.95)	0.98 (0.97–0.99)	0.98 (0.97–0.98)	0.98 (0.97–0.98)
Denture use					
All-cause mortality					
Without dentures	1,523 (144.8)	Reference	Reference	Reference	Reference
With dentures	603 (96.1)	0.66 (0.60–0.73)	0.88 (0.80–0.97)	0.79 (0.71–0.87)	0.79 (0.71–0.88)
Cardiovascular disease mortality					
Without dentures	304 (36.6)	Reference	Reference	Reference	Reference
With dentures	131 (24.5)	0.67 (0.55–0.82)	0.90 (0.73–1.11)	0.81 (0.64–1.01)	0.80 (0.64–1.00)

(Continued)

TABLE 2 (Continued)

Characteristic	Number of deaths (incidence rate, per 1,000 person-year, %)	Unadjusted model	Model 1	Model 2	Model 3
		HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Respiratory disease mortality					
Without dentures	154 (19.1)	Reference	Reference	Reference	Reference
With dentures	62 (12.0)	0.63 (0.47–0.84)	0.79 (0.58–1.06)	0.71 (0.51–0.98)	0.66 (0.48–0.92)
Cancer mortality					
Without dentures	61 (7.7)	Reference	Reference	Reference	Reference
With dentures	46 (8.9)	1.15 (0.78–1.68)	1.17 (0.79–1.73)	0.92 (0.60–1.43)	0.90 (0.58–1.40)
Other cause mortality					
Without dentures	957 (100.5)	Reference	Reference	Reference	Reference
With dentures	333 (57.9)	0.60 (0.53–0.68)	0.86 (0.76–0.98)	0.76 (0.67–0.87)	0.77 (0.68–0.88)

HR, hazard ratio; CI, confidence interval. Model 1: adjusted for baseline age, sex, residence, living arrangement, economic status, education, and marital status. Model 2: further adjusted for smoking status, drinking status, regular exercise, fruit intake, vegetable intake, meat intake, fish intake, and egg intake, and further adjusted for denture use in the natural tooth model and further adjusted for the number of natural teeth in the denture use model. Model 3: further adjusted for body mass index, hypertension, heart disease, diabetes mellitus, respiratory disease, and cancer.[a]Test for trend based on the variable containing the median value for each group.

The findings of this study are consistent with previous prospective studies in which tooth loss was associated with a higher risk of all-cause mortality (11, 25–28). A cohort study found that older adults who experience tooth loss were at a higher risk of mortality, and the use of dentures was found to have a protective effect against all-cause mortality, regardless of the extent of tooth loss (14). A study of 50,045 people between the ages of 40 and 75 in northeastern Iran found that participants with the most severe tooth loss had a higher overall mortality rate than those who lost the fewest teeth (25). Our results and previous studies suggest that preserving as many natural teeth as possible and using dentures can reduce the risk of all-cause mortality. However, some studies have reported results that are inconsistent with our findings. For example, in a study of community-dwelling older adults in Japan, Maekawa et al. (28) found that functional teeth were a significant independent risk factor for mortality, whereas the number of present teeth was not. Additionally, two other studies reported no associations between the number of teeth and mortality among older men (16, 17). Possible explanations are differences in the target study participants' age, geographic location, lifestyle, ethnicity, or cultural ecology. Unlike existing studies that are limited to a single geographical location or a small area, our study covered a large area of 23 research sites in 23 provinces in mainland China. In addition, different dietary patterns related to oral health in different study populations may affect the association between dental status and all-cause mortality.

Additionally, the relationship between tooth loss, denture use, and mortality associated with specific causes is noteworthy. In cause-specific analyses, participants with 0 and 1–9 teeth are at a higher risk for CVD, cancer, and other cause of mortality. Similarly, among participants without dentures, those with 0 teeth had a higher risk of respiratory disease mortality. This is consistent with previous studies showing a link between tooth loss and CVD mortality (26) and respiratory mortality (10). Our study adds to the literature by demonstrating that denture use may reduce cause-specific mortality among older adults with tooth loss. Specifically, our study found that participants with dentures in those with partial tooth loss had lower CVD mortality, respiratory disease mortality, and other cause mortality than those without dentures. Limited studies have investigated the relationship between denture use and cancer mortality. While some studies suggest that good oral health may reduce the risk of certain types of cancer (29), there is no evidence that denture use alone can reduce the risk of cancer mortality. The relationship between tooth loss, denture use, and cancer mortality is complex and may be influenced by factors such as cancer type and disease stage. Furthermore, the limited number of cancer-related deaths within our sample may have led to a wide confidence interval of our findings, indicating the necessity for further research into the relationship between tooth loss, denture use, and cancer, including the need to increase the sample size.

However, we found that the HRs for tooth loss were all relatively close to 1, suggesting that the associations between tooth loss and mortality may not be very strong. Notably, small effect sizes do not necessarily indicate that the relationship between tooth loss and mortality is not significant. In some cases, an HR closer to 1 may be meaningful and clinically relevant, particularly if the outcome being studied significantly impacts a participant's health outcomes. Additionally, our study was conducted on a large population-based sample, enhancing our findings' generalizability. The number of natural teeth may be a risk marker rather than a risk indicator of mortality. However, our study provides valuable insights into the potential health consequences of tooth loss in older adults, highlighting the importance of maintaining good oral health as we age.

The mechanism underlying the associations of tooth loss and denture use with all-cause and cause-specific mortality remains uncertain, but several possibilities have been proposed. First, natural tooth loss can affect chewing ability, reduce dietary diversity, and induce poor oral hygiene (30). This may result in reduced overall nutrient intake and can increase the risk of systemic inflammation (31) and chronic diseases such as CVD (32) and cancer (33). Our study found a significant association between tooth loss and insufficient intake of essential food groups at baseline, including vegetables, fruits, meat, and fish. However, it is unclear whether the diet is a confounding factor or a link between tooth loss and mortality. A poor diet could be a risk factor for increased mortality, but it could also be a consequence of tooth loss. While our study cannot differentiate between the two possibilities, it is important to consider both when interpreting the results. Therefore, further studies considering diet as a potential confounder or mediator are warranted. Furthermore, natural tooth loss

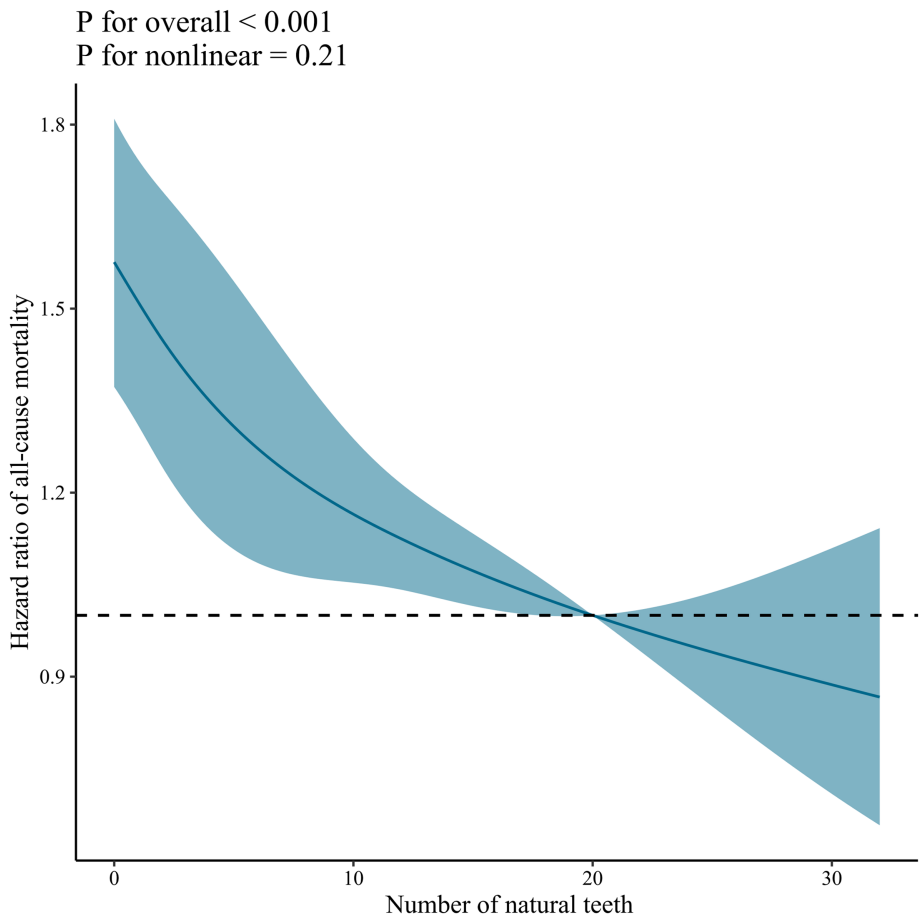

FIGURE 2
Dose–response association between the number of natural teeth and all-cause mortality. Solid blue lines are multivariable-adjusted hazard ratios, with shaded areas showing 95% confidence intervals derived from restricted cubic spline regressions with four knots at the 5th, 35th, 65th, and 95th percentiles. The reference was set at 20 natural teeth. Multivariate models were adjusted for baseline age, sex, marital status, education, residence, living arrangement, economic status, smoking status, drinking status, regular exercise, denture use, body mass index, hypertension, heart disease, diabetes mellitus, respiratory disease, cancer, fruit intake, vegetable intake, meat intake, fish intake, and egg intake.

can cause psychological distress and social isolation, contributing to poorer mental health and ultimately increased mortality (34). However, our study did not investigate the association between tooth loss with psychological distress and social isolation in older adults. Thus, further studies are required to verify the findings and elucidate the underlying mechanisms. Restorative treatments, on the other hand, such as denture use, are frequently used to improve chewing function and are thought to improve nutritional status (35, 36). Our baseline data showed that participants with dentures were more likely to consume adequate amounts of vegetables, fruits, meat, fish, and eggs than those without dentures. In terms of public health implications, ensuring that people who have lost teeth receive appropriate restorative treatment restores oral function. It improves swallowing function (37) and maintains protein intake, playing an essential role in maintaining the health of old adults, such as reducing mortality in old adults.

Tooth loss can result from various factors, such as tooth decay and gum disease (38). In addition, poor oral hygiene (39), smoking (40), and medical conditions, such as diabetes (41) and osteoporosis (42), may also contribute to tooth loss. Aging can also play a role, as the enamel on teeth gradually wears down over time. Another notable point in this study is that age may modify the relation between tooth loss and all-cause mortality with a stronger positive association in individuals aged<80 years. It may be that older adults aged <80 years may be more socially active and engaged in their communities (43), and tooth loss could impact their ability to communicate and interact with others (44). This social isolation could exacerbate the negative impact of tooth loss on their mental and emotional well-being. In contrast, older adults aged ≥80 years may have a higher level of resilience and adaptability to the adverse effects of tooth loss. They may have experienced tooth loss earlier in their lives and have found ways to cope with its impacts. Overall, the findings of our study suggest that age is an essential factor to consider when examining the association between tooth loss and mortality. It is important to further explore the mechanisms underlying this relationship and identify strategies to promote oral health and prevent tooth loss in older adults. However, our study was designed as an observational cohort study, with inherent limitations in establishing causality. Further research, such as randomized controlled trials, will establish a causal relationship between tooth loss and all-cause mortality.

Strengths and limitations

This study provides a valuable contribution to the existing literature on the role of the number of natural teeth and dentures in

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TABLE 3 Combined effects of the number of natural teeth and denture use on all-cause and cause-specific mortality.

Characteristic	Number of deaths (Incidence rate, per 1,000 person-year, %)	Unadjusted model	Model 1	Model 2	Model 3
		HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
All-cause mortality					
20+	214 (56.7)	Reference	Reference	Reference	Reference
10–19 with dentures	51 (51.9)	0.91 (0.67–1.24)	0.88 (0.65–1.19)	0.87 (0.64–1.19)	0.87 (0.64–1.18)
10–19 without dentures	206 (96.4)	1.71 (1.41–2.07)	1.21 (1.00–1.47)	1.17 (0.96–1.42)	1.16 (0.96–1.41)
1–9 with dentures	122 (80.6)	1.43 (1.14–1.78)	1.21 (0.97–1.51)	1.18 (0.94–1.48)	1.17 (0.93–1.46)
1–9 without dentures	535 (174.4)	3.10 (2.65–3.64)	1.51 (1.28–1.79)	1.47 (1.24–1.74)	1.48 (1.25–1.75)
0 with dentures	402 (130.2)	2.31 (1.95–2.72)	1.39 (1.17–1.65)	1.35 (1.14–1.60)	1.37 (1.15–1.62)
0 without dentures	596 (266.9)	4.79 (4.09–5.60)	1.80 (1.52–2.14)	1.71 (1.44–2.03)	1.71 (1.44–2.03)
p-value for trend[a]		<0.001	<0.001	<0.001	<0.001
Cardiovascular disease mortality					
20+	45 (13.2)	Reference	Reference	Reference	Reference
10–19 with dentures	14 (15.6)	1.17 (0.64–2.14)	1.15 (0.63–2.10)	1.17 (0.64–2.14)	1.26 (0.69–2.30)
10–19 without dentures	46 (25.4)	1.91 (1.27–2.88)	1.28 (0.84–1.93)	1.25 (0.83–1.90)	1.30 (0.86–1.98)
1–9 with dentures	26 (19.6)	1.48 (0.91–2.40)	1.21 (0.75–1.97)	1.19 (0.73–1.93)	1.21 (0.74–1.97)
1–9 without dentures	113 (48.9)	3.64 (2.57–5.14)	1.56 (1.08–2.25)	1.55 (1.07–2.24)	1.65 (1.14–2.38)
0 with dentures	87 (34.9)	2.60 (1.81–3.73)	1.45 (1.00–2.10)	1.41 (0.98–2.05)	1.55 (1.07–2.25)
0 without dentures	104 (74.2)	5.48 (3.87–7.78)	1.75 (1.20–2.56)	1.69 (1.15–2.47)	1.85 (1.26–2.71)
p-value for trend[a]		<0.001	0.006	0.012	0.003
Respiratory disease mortality					
20+	30 (8.9)	Reference	Reference	Reference	Reference
10–19 with dentures	8 (9.1)	1.02 (0.47–2.23)	1.01 (0.46–2.21)	0.94 (0.43–2.06)	0.94 (0.42–2.07)
10–19 without dentures	25 (14.1)	1.59 (0.93–2.70)	1.13 (0.66–1.94)	1.01 (0.59–1.75)	1.02 (0.59–1.78)
1–9 with dentures	8 (6.2)	0.70 (0.32–1.52)	0.62 (0.28–1.35)	0.61 (0.28–1.33)	0.57 (0.26–1.25)
1–9 without dentures	54 (24.6)	2.74 (1.75–4.28)	1.55 (0.96–2.48)	1.46 (0.91–2.36)	1.47 (0.91–2.37)
0 with dentures	41 (17.1)	1.90 (1.19–3.05)	1.28 (0.79–2.08)	1.21 (0.74–1.96)	1.22 (0.75–1.98)
0 without dentures	50 (37.1)	4.10 (2.61–6.46)	1.80 (1.10–2.96)	1.63 (0.99–2.68)	1.75 (1.06–2.87)
p-value for trend[a]		<0.001	0.07	0.12	0.09
Cancer mortality					
20+	17 (5.1)	Reference	Reference	Reference	Reference
10–19 with dentures	6 (6.8)	1.35 (0.53–3.43)	1.36 (0.53–3.47)	1.32 (0.52–3.37)	1.14 (0.44–3.00)
10–19 without dentures	14 (8.0)	1.58 (0.78–3.21)	1.67 (0.82–3.44)	1.75 (0.85–3.59)	1.74 (0.84–3.59)
1–9 with dentures	11 (8.4)	1.66 (0.78–3.55)	1.76 (0.82–3.79)	1.71 (0.80–3.70)	1.64 (0.76–3.55)
1–9 without dentures	23 (10.8)	2.12 (1.13–3.96)	2.36 (1.22–4.59)	2.30 (1.18–4.49)	2.35 (1.20–4.57)
0 with dentures	26 (10.9)	2.15 (1.17–3.96)	2.30 (1.23–4.33)	2.17 (1.15–4.10)	2.27 (1.20–4.29)
0 without dentures	10 (7.9)	1.56 (0.71–3.40)	1.77 (0.76–4.10)	1.72 (0.74–4.00)	1.77 (0.76–4.11)
p-value for trend[a]		0.01	0.01	0.01	0.01
Other cause mortality					
20+	122 (34.1)	Reference	Reference	Reference	Reference
10–19 with dentures	23 (25.0)	0.73 (0.47–1.14)	0.68 (0.44–1.07)	0.67 (0.43–1.05)	0.66 (0.42–1.03)
10–19 without dentures	121 (61.4)	1.80 (1.40–2.32)	1.17 (0.91–1.51)	1.14 (0.88–1.47)	1.13 (0.87–1.45)
1–9 with dentures	77 (53.8)	1.58 (1.19–2.10)	1.27 (0.95–1.69)	1.22 (0.91–1.62)	1.2 (0.90–1.60)
1–9 without dentures	345 (126.4)	3.72 (3.03–4.58)	1.50 (1.21–1.87)	1.45 (1.17–1.81)	1.45 (1.17–1.81)
0 with dentures	248 (88.7)	2.60 (2.10–3.23)	1.41 (1.13–1.76)	1.35 (1.08–1.69)	1.38 (1.10–1.72)

(Continued)

TABLE 3 (Continued)

Characteristic	Number of deaths (Incidence rate, per 1,000 person-year, %)	Unadjusted model	Model 1	Model 2	Model 3
		HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
0 without dentures	432 (218.1)	6.45 (5.27–7.89)	1.90 (1.53–2.37)	1.78 (1.43–2.22)	1.76 (1.41–2.20)
p-value for trend[a]		<0.001	<0.001	<0.001	<0.001

HR, hazard ratio; CI, confidence interval. Model 1: adjusted for baseline age, sex, residence, living arrangement, economic status, education, and marital status. Model 2: further adjusted for smoking status, drinking status, regular exercise, fruit intake, vegetable intake, meat intake, fish intake, and egg intake. Model 3: further adjusted for body mass index, hypertension, heart disease, diabetes mellitus, respiratory disease, and cancer.[a]Test for trend based on the variable containing the median value for each group.

predicting all-cause and cause-specific mortality in older adults. This study's strengths include using a large sample of older adults, examining the number of natural teeth, and using dentures as separate measures of dental health. The number of natural teeth and the use of dentures provide different information about oral health status and are dependent and correlated variables. Therefore, separately analyzing them may allow for a more nuanced understanding of the relationship between oral health status and other variables of interest. It can also provide valuable information for researchers and policymakers in designing interventions and policies to improve oral health outcomes. However, this study has several limitations to consider. First, the study was based on the self-reported number of natural teeth and denture use, which may be subjected to reporting bias. Second, we could not assess the effect of changes in dental health over time, as dental health was only assessed at baseline. Third, we did not have information on the cause of tooth loss, which could affect the association between the number of natural teeth and mortality. Fourth, the study was limited to older adults in China, and the findings may not be generalizable to other populations. Finally, as with any analysis, residual confusion caused by unmeasured factors cannot be eliminated.

Conclusion

In conclusion, our study indicates that older adults with a higher number of tooth loss and who do not use dentures are at increased mortality, particularly from all-cause, cardiovascular disease, cancer, and other causes. These findings indicate that maintaining adequate natural teeth is crucial in preventing mortality among older adults. They also highlight the potential benefits of denture use in mitigating the adverse effects of tooth loss on overall and cause-specific mortality.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://opendata.pku.edu.cn/dataverse/CHADS.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of Peking University (IRB00001052-13074). The patients/participants provided their written informed consent to participate in this study.

Author contributions

All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1194054/full#supplementary-material

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Promoting active aging through assistive product design innovation: a preference-based integrated design framework

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Background: With the accelerating trend of global aging, over one billion people need to use one or more types of assistive products. However, the high abandonment rate of current assistive products is affecting the quality of life of the older adults, posing challenges to public health. Accurately capturing the preference factors of the older adults in the design process is an important way to improve the acceptance of assistive products. In addition, a systematic approach is needed to translate these preference factors into innovative product solutions. These two issues are less addressed in existing research.

Methods: First, the evaluation grid method was used to conduct in-depth interviews with users and extract the structure of preference factors for assistive products. Quantification theory type I was used to calculate the weight of each factor. Secondly, universal design principles, TRIZ theory's contradiction analysis techniques, and invention principles were used to translate the preference factors into design guidelines. Then, finite structure method (FSM), morphological chart, and CAD techniques were used to visualize the design guidelines as alternatives. Finally, Analytic Hierarchy Process (AHP) was used to evaluate and rank the alternatives.

Results: A Preference-based Assistive Product Design Model (PAPDM) was proposed. The model includes three stages: definition, ideation, and evaluation. A case study on walking aid demonstrated the execution of PAPDM. The results show that 28 preference factors influence the four psychological needs of the older adults: sense of security, sense of independence, self-esteem, and sense of participation. These psychological needs were reflected in the shape, color, material, universality, user-friendly, reliability, and smart functions of assistive products. The preference factors were transformed into five design guidelines, and three alternatives were generated. Finally, the evaluation concludes that solution C was the optimal solution.

Conclusion: The PAPDM framework provides designers with a transparent, progressive approach to designing assistive products that meet unique needs and preferences of older adults. This enhances objectivity and scientific rigor in assistive product development, avoiding blind design and production. By considering the perspective of older adults from the outset, we can avoid high abandonment rates of assistive products and contribute to promoting active aging.

KEYWORDS

active aging, assistive products, preference-based design, Miryoku engineering, evaluation grid method (EGM), universal design (UD), TRIZ

1. Introduction

The pace of population aging is much faster than in the past. according to the WHO, Between 2015 and 2050, the proportion of the world's population over 60 years will nearly double from 12 to 22% (1). However, as people's life expectancy increases, poor health conditions become more common (2). This issue poses a major public health challenge (2–8).

Promoting active aging has become a timely policy response for these countries in response to the challenges posed by accelerated population aging (9). Extensive research has shown that assistive technology (AT) can promote important dimensions of active aging (e.g., physical health, mental health, social participation, and lifelong learning) (6–8, 10–12). It is a fundamental part of broader, integrated health and social system solutions for supporting older adults (13).

Assistive products (Aps) are an essential component of the implementation of assistive technology policies (14) and are also considered to be an important contribution to public health. The use of APs is a common strategy for community elders to maintain their independence and cope with daily activities (15). over one billion people need one or more assistive products. The majority of these are older people and people with disabilities (16). And that number is expected to increase to more than 2 billion by 2050. However, due to cost, availability and financial issues, only about 10% of those in need have access to these products. This leads to impairment of the ability to perform activities of daily living (ADLs) and reduced life satisfaction (LS) (2) in Older Adults (OA). Effective tools and outcomes have been developed to help increase the accessibility of assistive products for older adults, including the Priority Assistive Product List (APL) developed by WHO (16), Assistive Product Explorer (ASPREX) from Global Collaboration On Assistive Technology (GATE) (17), International standards for Assistive products (ISO 9999:2022), National standards for assistive product in China (GBT16432-2016), APs database (18), EASTIN (19) ATAust (20) etc. In addition, rich study also reflect the positive attitude of the academia toward assistive products research. According to the six domains proposed by APL (16)., mobility aids (21–29) have received the most attention in current research, followed by visual (30–33), hearing (34), cognition (35), and environment (36–39) APs. The above confirms that stakeholders have made appreciable efforts in the accessibility of APs, but what is not optimistic is that the high abandonment rate of Aps remains the recent consensus (3–5). Reasons for older adults to abandon the use of assistive devices often include personal factors [e.g., health status (4), Ethics (40), Privacy (41) stigma (42), unmet needs (43)], intervention factors [e.g., design (44), function (45) and services (44)] and environmental factors [e.g., social (46) and discriminated (4)].

It is interesting to note that these findings are coincidentally related to the psychological needs or user experience (47) of the older adults. Preference as a user experience element can improve user acceptance of a product (48). In other words, identifying user preference factors can reduce product abandonment rates. Numerous studies indicated that preferences were key factors for New Product Development (NPD) (49–53). However, the needs and preferences of the older adults are very different from other age groups (54). High-speed aging also puts new demands on the development of APs (55). Although preferences are important, little is known to date about preferences for assistive devices for older adults (56–59). In particular, to our knowledge, there is no study that scientifically captures older adults' preference factors and effectively translates them into assistive device design.

In addition, recent research on design of Aps (APD) suggest that producers should weaken the targeting of their products in order to preserve the dignity of the users and make the products actively used (6, 60, 61). This is right in line with the principles of universal design (similar terms arising from different social cultures includeBarrier-free design, inclusive design (62), design for all These approaches all take the needs of a broader spectrum of people into account in the design process (63). Extensive research has proven that universal design (UD) facilitates social participation (54, 64, 65) and the implementation of active aging policies (54) but the challenge is that UD is difficult to implement in the enterprise (65).

Therefore, it is necessary to establish a specific framework in APD that can facilitate the implementation of UD. To date, previous studies have attempted to establish a number of APD methods aimed at increasing the use of APs. A part of scholars applied the existing single method, technique or principle to the development and design of APs and implemented cases for validation. For example, participatory design (66), synesthetic design (67), Quality Function Deployment (QFD) (68), AHP (69), Sensory Substitution (SS) (70) and Makerspaces (71). Some other scholars have attempted to integrate different well-established methods to create a completer and more integrated framework. Hwang and Park (72) proposed the knowledge of DHSfXs to create alternative solution concepts for assistive device design teams based on 77 Design Heuristics (73). Xassess Teresa's team has built Xassess, an evaluation tool for assistive product design from an interdisciplinary perspective (74). Santos and Silveira (75) integrated user-centered design and additive manufacturing technologies to establish the APD method called AT-d8sign (75). This provides a low-cost and DIY framework for assistive technology design (50). Other studies on the APD framework include a Fuzzy Kano-AHP-DEMATEL-QFD Approach (76), QFD-ANP (77), Usability Context Analysis (UCA) SWOT Analysis TOWS matrix (37), Axiomatic Design (AD) and Theory of Solving Inventive Problems (TRIZ) (78). In the two APD research paradigms above, the use of independent methods is more in-depth and specific, but cannot cover a more complete design process. Whereas, an integrated framework may enable the independent methods to complement each other's strengths, most of the research on integrated frameworks has not been validated by effective cases. In addition, these APD studies barely include the preference factors of older adults.

Based on these issues, There are two primary aims of this study: (1) to determine the way to analyze the preference factors of older adults for APs. (2) to develop a new APD integrated design framework and validate its effectiveness using case studies. This work has dual implications, first it provides a qualitative and quantitative description of older adults' preferences for APs, and meeting older adults' preferences in the early stages of design can be a good way to reduce APs abandonment rates. Incorporating

UD principles into research can expand the diversity of user groups and thus expand the market for APs. This bolsters the notion expressed in the WHO report that consumer electronics and assistive technology are integrating more and more (79). Second, an integrated APD framework is more robust and conducive to the practice of assistive product design. This promotes the social participation and active aging of older adults.

2. Theoretical background

2.1. Preference-based design and Miryoku engineering

Preferences refer to an individual's attitude toward a set of objects, typically reflected in an explicit decision-making process (80). In the consumer decision process, the user's preference factor is Attractiveness of the products. This is a key factor in consumer purchase decisions (81). In order to develop attractive products and systems, Junichiro Sanui and Masao Inui proposed Miryoku Engineering as a preference-based design technique in 1985 (81). It later became a part of Kansei Engineering (82), but Miryoku Engineering places a greater emphasis on customers' subtle inner feelings (53). Evaluation Grid Method (EGM) is the key method used to extract user preference factors in the Miryoku Engineering system (83).

The main purpose of Evaluation Grid Method is to thoroughly explore users' inner feelings to extract details of consumers' cognitive structures and to convert them into concrete factors of assessment as a basis of design (53). EGM is a semi-structured interview method developed by Junichiro Sanui (84) based on Kelly's Personal Construct Theory (85). It is implemented in the following steps:

1. The original evaluation items (OEIs) of samples were obtained by asking respondents for pairwise comparisons.
2. Laddering technique was used to extract abstract evaluation items (AEI) and concrete evaluation items (CEI) on the basis of OEI.
3. Visualize the above cognitive structure.

Researchers have validated the effectiveness of the EGM in a variety of fields. Research in the field of product design is the most abundant. Ma et al. (53) used EGM to analyze consumer attractiveness to 3C products and proposed design strategies for new product attractiveness (53). Xi et al. (86) analyzed the form attractiveness of electric vehicle (BEV) (86). Ko et al. (87) analyzed the effect of personality traits on consumption preferences using office chairs as an example (87). Zhang and Li (83) measured consumer attraction factors for green products aimed at promoting environmental protection (83). Wei and Ma (88) evaluated the elements of attractiveness in the design of attractive children's books (88). INOUE studied the needs of multiple users in mechanical pencil design (89). Wu et al. (90) used EGM to establish a design strategy for Healing Products (90). Research on EGM in other areas including space (91–93), digital products (94–96), events (97, 98), behavior (99, 100), experience (101) etc. The above literature is a sufficient proof of the effectiveness of EGM for extracting user preferences. However, so far, research on the use of EGM for assistive devices is still limited.

In this study, EGM was used to extract the preference structure of older adults for APs in the first phase of the APD framework. Thus, the diverse needs of the older adults can be accurately understood in the early stages of design.

2.2. Quantification theory type I

Quantification Theory Type I (QTT1), proposed by Hayashi in 1976 (102), is a multiple regression analysis designed to assign values to qualitative data. Nagamachi uses QTT1 in Kansei Engineering to analyze qualitative data such as consumer feelings and images (82). In addition, a large number of studies have used QTT1 to analyze the weights of qualitative data generated by EGM (83, 96, 98, 100, 103). Techniques such as multiple linear regression (104), Taguchi's method (105), and conjoint analysis (106) have also been used to explain the relationship between the independent and dependent variables. but, QTT1 is simpler and more effective. A review of previous studies revealed that when analyzing qualitative data of EGM, the results of QTT1 are a good representation of the weighting relationships between subjective demands, objective attributes and sub-attributes. However, contradictory relationships often exist in these data. For example, some studies have shown that the contradiction increases with the design attributes (54). The older adults also have contradictions when using APs (107). These contradictions, which may influence the next design decision, need to be resolved in a reasonable way. However, this has hardly been discussed in past studies. In the present study, QTT1 was used in the first phase of the APD framework to quantify the preference factors of older adults. The calculated results served as the basis for the design ideation of the second phase. In addition, contradictory relationships in the QTT1 results were further discussed to fill the research gaps.

2.3. Theory of innovation problem solving (TRIZ)

TRIZ, a term from the Russian acronym, is a theory for solving inventive problems proposed by the Soviet engineer Grich Altshuller in 1946 (108). TRIZ solves inventive problems by using a structured approach to identify and eliminate contradictions (109).

TRIZ defines two types of contradictions: Physical Contradictions (PCs) (the direct opposition of two parameters formulated by one and the same system) and Technical Contradictions (TCs) (a situation in which the improvement of a parameter A leads to the deterioration of a parameter B) (110). PCs are solved by the separation principle while TCs are solved by the contradiction matrix and 40 invention principles. Afterwards, the TRIZ invention principles are combined with the domain knowledge of the experts to generate innovative solutions that meet customers' requirements.

TRIZ is considered to be one of the most effective tools for conceiving engineering designs and solving problems (111). TRIZ can effectively improve the novelty and diversity of ideation (112).

Also, TRIZ is proven to be a good method for solving problems involving contradictions (113).

The value of TRIZ has been proven in a wide range of research area. In the field of product design, TRIZ, which has been applied to the study of medical equipment (114), Sustainable Product (115), service design (116), eco-design (117), Mechanical design (118, 119), conceptual design (120), Cultural and Creative Design (121), Biologically Inspired Design (122), Structural Design (123), Ergonomic analysis (124), Design Education (125), aims to enhance the reliability of the innovation process based on the scientific method.

Although TRIZ is a powerful tool for design conceptualization, it does not seem to be able to establish the key issues of innovation, nor does it provide a method for evaluating alternatives (126). Therefore, in many studies TRIZ is used in combination with other methods, such as QFD (127, 128), Axiomatic Design (129), Text Mining (130), Genetic Algorithm (130) TOPSIS (115), DEMATEL (131) and fuzzy theory (126), as a more complete framework in the innovation process. Few studies have integrated TRIZ with EGM and QTT1 to study preference-based design.

TRIZ theory contains many tools, and the present study uses several of the most widely used and effective TRIZ tools in the field of product design research including the 40 principles of invention, the contradiction matrix, and the separation principle. In order to propose innovation guidelines for APD in the second phase. The implementation process is as follows.

1. Identify specific contradictions in design elements and translate them into TRIZ contradictions (TC and PC).
2. Resolve technical contradictions (TCs): use the contradiction matrix and the invention principle.
3. Resolve physical contradictions (PCs): use the separation principle (including spatial separation, temporal separation, conditional separation and overall local separation) combined with the invention principle.
4. Propose a specific innovation strategy: propose a specific innovation strategy based on the broad invention principle.

2.4. Finite structure method

The main framework of this study references design thinking (132), a process of exploration based on divergent-convergent logic (133). The product function is defined after the TRIZ proposed innovation strategy. However, different combinations of the main functions and sub-functions of a product can take various forms (134). Appropriate methods based on divergence-convergence are needed to achieve a more rational product form.

Finite Structure Method (FSM), a method that can change the spatial layout of a product is used in the framework of this study, which can obtain a rational layout of product functions and provide support for product form design. This is the consensus of several studies (134–137). In this paper, FSM is used to generate various layouts of APs functions. The specific operation steps of FSM are shown as follows:

1. Identify a finite number of functional modules for the target product.
2. Disperse the possible layouts in 2D or 3D geometries.
3. Converge various layouts based on design goals and feasibility to obtain the best solution.

2.5. Morphological charts

Morphological charts are design tools for generating integrated conceptual design solutions for design problems in a systematic and analytical manner (138, 139). Theoretically, at least hundreds of specific concepts can be obtained by using morphological diagrams to disperse the product sub-functions. Since its introduction by Zwicky (140), morphological charts have been used in a variety of research areas, including Sustainable Design (141), Human Factors Design (142), Conceptual Design (143), Product-Service System design (144). In addition, the use of morphological charts in combination with other methods [e.g., QFD (145), ANP (146), TRIZ (147, 148) and Fuzzy evaluation (135)] into a hybrid framework is also a popular research paradigm. However, the combination of methods included in this study is different from existing studies, especially the use of morphological charts for the design of assistive devices for the older adults is limited. The specific procedures for the morphological charts in this work are taken from the Delft Design Guide (139) published by Delft University of Technology.

2.6. Analytic hierarchy process

Analytic Hierarchy Process (AHP) (149) is the most popular multi-criteria decision making (MCDM) tool invented by Saaty (150). As a decision analysis technique, it can evaluate complex multi-attribute alternatives between one or more decision makers (151). The literature shows that AHP is mainly used to select the best concept among the generated alternatives in the design field (152). The detailed steps of AHP are shown below:

1. Define the problem and determine its objectives, evaluation criteria, evaluation objects and construct their decision models.
2. Each evaluation criterion was scored by pairwise comparisons and each alternative was scored according to each evaluation criterion.
3. Build their comparison matrix.

$$\text{C.R.} = \frac{C.I.}{R.I.}, \text{C.I.} = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

4. Calculations are performed to find the maximum eigenvalue, consistency index C.I., consistency ratio C.R. and normalized value for each criterion/alternative. The algorithm for the consistency relationship is shown in Equation (1). R.I. is the random index. If the maximum eigenvalues (λ_{max}), C.I. and C.R. are reasonable (C.R. < 0.1), the decision is made based on the normalized values; otherwise, the comparison matrix should be checked for logical errors until these values pass the consistency test.

AHP has been widely used in the design field. such as determine the importance weights for the customer requirements (153),

product technical requirements (PTRs) (154), Customer-driven product design process (155), evaluate design concepts (156), select the optimum green product design (157), Analyze product style (158), modular product design (159), product structure design (160), product-service systems conceptual design (161) etc. The integrated AHP makes more realistic and promising decisions than the stand-alone AHP (162). AHP is mostly used in combination with TOPSIS, quality function deployment (QFD), meta-heuristics, SWOT analysis and data envelopment analysis (DEA) to form an integrated framework. Hsiao (158) combined AHP and genetic algorithms to construct a computational product form design model. Zhu et al. (163) combines AHP, QFD and PUGH for medical device design. Karasan et al. (164) discussed the combination of AHP and DEMATEL for customer-oriented product design. Thus, in light of the foregoing analysis, AHP has been sufficiently proven to be effective. In this study, AHP is used to evaluate the alternatives in the third stage of the design model to obtain the optimal solution.

3. Proposed preference-based assistive product design model

As described and reviewed in the parts I and II, from a problem-oriented perspective, exploring the factors of older adults' preference for APs is beneficial in addressing the problem of APs abandonment. In terms of methodological orientation, most of the traditional independent methods address a single problem in the design process, and it is also difficult to cover more stages of the design process in the traditional combined form of these methods. In addition, the practicality of UD theory is currently inadequate. For these reasons, this paper proposes a Preference-based Assistive Product Design Model (PAPDM) as shown in Figure 1. The integrated design model consists of three phases: Definition phase, Conception phase and Evaluation phase. The specific implementation steps are shown below:

Phase I: Definition

Step 1: Data collection. Define the design problem, set keywords, select databases (such as integrated search engines, patent databases, research databases, vertical web-sites in the field, etc.) and create an assistive device design information table according to the international and national standards for APs. The APD information charts serves as the basis for subsequent research.

Step 2: Extract the user preference structure. Identify interviewees in diverse potential user groups of the target product and perform semi-structured interviews with them using the experimental samples. Visualize the user preference structure (including OEIs, AEIs and CEIs) using infographics.

Step 3: quantitative analysis. Collect data based on user preference structure by questionnaire method and obtain quantitative data of user preference structure by Quantification Theory Type I (QTT1).

Phase II: Ideation

Step 4: Generate innovation guidelines. The specific contradictions are identified based on the weights in the quantified CEIs, and specific contradictions are trans-formed into TCs and PCs. The innovation guidelines for the target products are generated using contradiction matrix, 40 invention principles, separation principle and UD principles to dissolve the TCs and PCs.

Step 5: Determine the layout of the product functional units. Based on the innovation guidelines, the Finite structure method (FSM) is used to analyze the possible combinations of product functional units and to determine the optimal functional unit layout.

Step 6: The shapes of each functional unit were diverged and converged to obtain several suggested alternatives using Morphological charts based on the functional unit layouts.

Step 7: Identify and visualize alternatives. Use computer-aided design techniques such as 3D or 2D graphic drawing software to visualize alternatives as concrete design alternatives.

Phase III: Evaluation

Step 8: Establish evaluation structure model. Set the OEIs as evaluation criteria and the alternatives as evaluation objects.

Step 9: Calculating weights. Calculate the weight of evaluation criteria and the weight of alternatives under each evaluation criterion.

Step 10: Obtain the optimal solution. Perform final evaluations and obtain optimal solution based on priority.

4. Case study

Mobility is a significant consideration in aging and public health research (165). As the population ages, mobility assistive devices are the most common type of APs used by older adults (15, 166), but they are also abandoned more frequently than other categories of Aps (167) for possible reasons such as stigma, inferior quality, and unmet needs as mentioned in section 1 of the paper. Based on the above, we chose walking aids as the target product for the case study, with the aim of demonstrating how PAPDM can be applied in a design scenario. The detailed steps for implementation of PAPDM are listed in the following sections.

4.1. Phase I: definition

4.1.1. Data collection

First, the research team set keywords at the beginning of data collection. The terminology of walking aids was referenced to international standards for APs and Chinese standards. The keywords included the near-synonyms (walking frames, rollators, mobility aids), sub-categories of walking aids, and other language descriptions of these words.

Second, appropriate information databases were selected based on the target products, including: comprehensive search engines, patent databases, international competition websites for product design (Reddot, IF, IDEA, etc.), e-commerce websites, scientific research databases, relevant vertical websites, assistive device databases, and self-publishing platforms. Boolean rules were used to collect information using keywords in order to obtain more comprehensive and effective information.

After the data collection, the team members obtained information on 57 walking aids products (including text, images or videos). After removing duplicate, low quality, and low relevance information, 26 typical walker products were obtained, and they

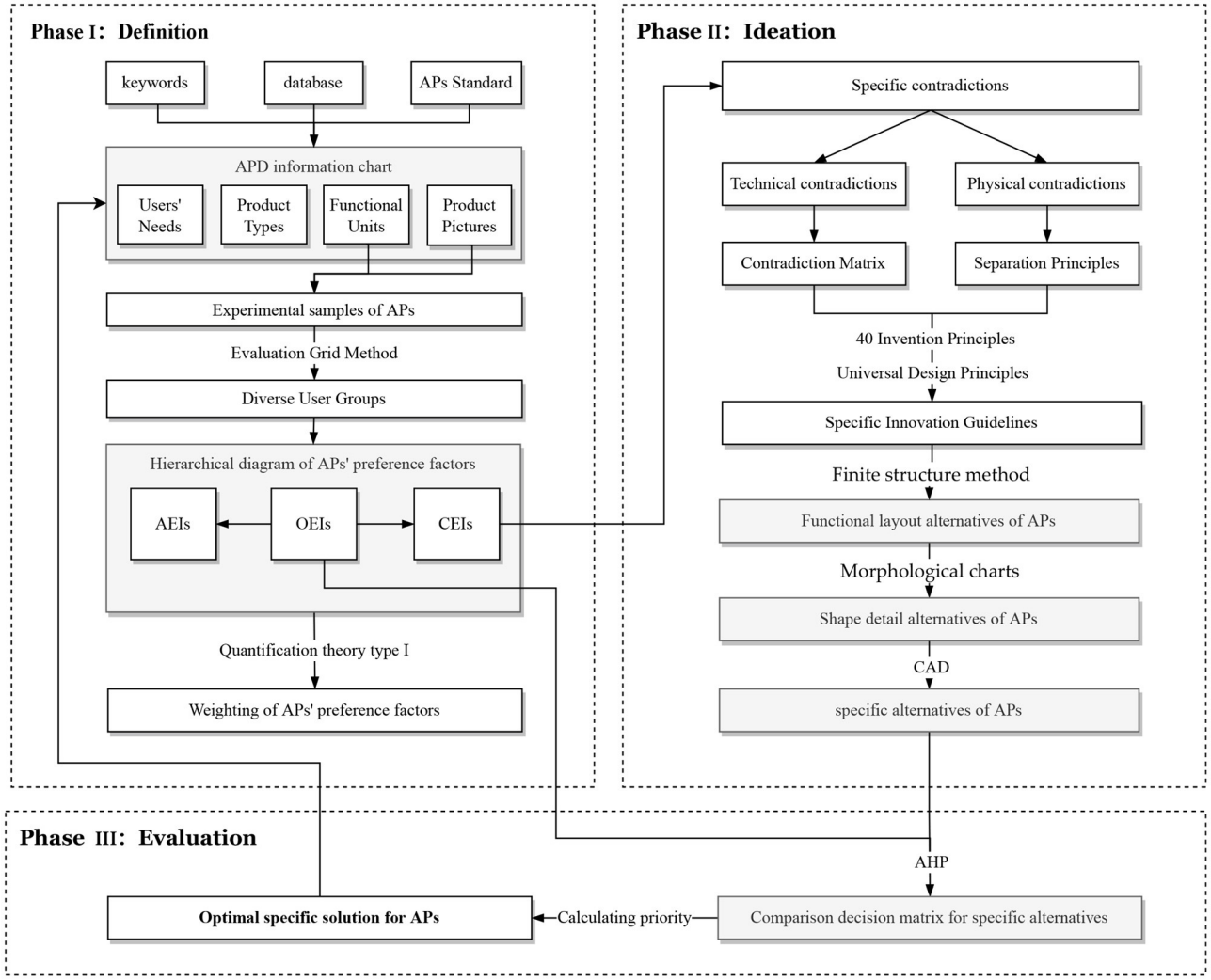

FIGURE 1
Preference-based assistive product design model (PAPDM).

were made into a walker product information table. Table 1 shows five of these typical samples. The APD information chart of the walking aid contains the name, picture and functional unit of each product. The research team also analyzed the design strategy of each product, the specific problem solved, and the corresponding TRIZ contradictions and TRIZ invention principles. The APD information chart was the basis for subsequent research.

4.1.2. Extract the user preference structure

After data collection, the research team identified target users of walking aids as interviewees. It is important to note that judgmental sampling was used instead of random sampling to select the interviewees. This method has the advantage of better cooperation and higher data retrieval rates, as well as greater representativeness. However, it is also important to acknowledge that there are certain limitations to judgmental sampling, as it may introduce bias in the selection of interviewees. In this study, the research team selected interviewees based on both the Universal Design (UD) theory and the Involvement Theory (168). The UD theory was used to consider diverse user groups with direct and potential needs for walking aids to achieve the universal design goals. Additionally, the Involvement Theory was used to select 15 highly involved individuals with relevant experience and expertise, such as their experience in using walking aids, caring for older adults who use walking aids, or their involvement in the design and development of assistive devices. The 15 interviewees (7 males and 8 females) included 4 older adults with more than 2 years of experience in using walking aids, 3 older adults with no experience but weak mobility, 2 older adults who had abandoned their walking aids, 2 older carers, 2 teachers in product design, and 2 experts in assistive device product companies. These interviewees were chosen based on their high involvement and expertise in the subject matter, which aligns with the principles of both the UD and Involvement theories.

TABLE 1 The APD information chart of walking aids.

No.	Name	Pictures	Functional units	Design Strategy	Specific problems	TRIZ contradictions	TRIZ invention principles
1	RAM WALK		Handles Frame Wheels	Streamlined appearance design	Stigma for the older adults	1, 33	2,13,15,25
2	Indoor Rollator		Handles Frame Shaft Wheels	Adjustable handrails	Ergonomic problems	35, 35	Separation Principles
3	TEWL		Handles Frame Shaft Seats Wheels	Foldable frame	The inconvenience of storage	8, 22	7
4	Let's Shop		Handles Frame Brakes Baskets Wheels	With soft shopping box	The inconvenience of carrying items when traveling	36, 33	12,17,26,32
5	Tri-Wheel Stair Walker		Handles Frame Brakes Wheels	Adjustable wheels	The inconvenience of walking up and down the stairs	35, 35	Separation Principles

Each walking aid product in the APD information chart was made into an A4 size color card. The research team was then divided into groups of 2 to interview the interviewees with 1 person asking questions and 1 person taking notes. First, interviewees were invited to select the preferred card after pairwise comparison of 42 typical walking aid cards and to give the reason (original evaluation items, OEIs) for that sample. Second, the researcher asked interviewees about the abstract reason behind this reason (AEIs) and what concrete reasons were needed to satisfy this (CEIs). This reveals the preferences of the interviewees and the product attributes mapped from these preferences. After the interviews, the researcher compiled the interview transcripts and then a hierarchical preference structure diagram (including 4 AEIs, 7 OEIs, and 26 CEIs) was created. The four colors in this chart represent the three-dimensional structure of the different preference factors in each AEIs. In addition, 7 specific contradictions were extracted from the CEIs after discussion between the research team and the EGM interviewees.

4.1.3. Quantification theory type I

Quantification theory type I was used to calculate the importance between user preference factors, aiming to provide guidance for the second stage of conceptualization. The research team designed the questionnaire based on a hierarchical preference structure diagram. The questionnaire consisted of two main parts; the first part was the basic user information. The second part consisted of four groups of questions (determined by the number of AEIs). Each set of questions includes the importance of each OEI in that AEI and what is the most important CEI. The research team distributed an online questionnaire based on the diverse user groups of EGM interviewees and obtained 105 valid questionnaires. For the calculation of QTT1, OEIs were set as the dependent

variable y while CEIs were set as the independent variable x. The quantitative relationship between the two was established by multiple regression analysis. Table 2 shows the results of QTT1. The coefficient of determination R^2 indicates the reliability of the results, the partial correlation coefficient indicates the importance of OEI, and the category score describes the contribution of CEIs. Positive values in the category scores suggest specific design features that contribute in the associated OEI, while negative values correspond to design features that should be avoided in the ideation phase.

4.2. Phase II: ideation

4.2.1. Generate innovation guidelines

At the beginning of the ideation phase, TRIZ was used to generate innovation guidelines. First, the research team analyzed seven specific contradictions in the EGM results (Figure 2) based on the results of QTT1 (Table 2). Five specific contradictions were finally identified and transformed into TRIZ contradictions. These 5 contradictions included 3 technical contradictions (TCs) and 2 physical contradictions (PCs). Next, the TRIZ invention principles of these contradictions were obtained based on the contradiction matrix and the separation principle (169). Finally, the research team used these TRIZ invention principles, UD principles, specific design strategies from the APD information chart and their own design experience to identify five specific innovation guidelines (including "Integration of different sizes of wheels", "Modular design", "Height- adjustable storage box", "Partial replacement of accessories" and "Restrictive structural design"). Table 3 shows the detailed process of how the specific contradictions were translated into innovation guidelines.

4.2.2. Determine the layout of the product functional units

Innovative guidelines for walking aids are to be achieved through specific functional units and their different layouts in the product. FSM was used to analyze and determine the layout of each functional unit of the walking aid, which also provides the basis for the appearance of the walking aid. First, this study identified six functional units of walking aids including wheels, handles, frames, seats, tables, and storage boxes based on the functional units of each walker in the APD information chart and similar functional units commonly used in other types of products. Next, different shapes were used to represent the corresponding units. The arrangement and combination of the size, number and different placement of the functional unit can provide sufficient form divergence. Finally, the research team extracted four layouts. Finally, the research team extracted four 3D layout options after discussion, as shown in Figure 3. In Layout 1, the front wheels of the walking aid have two kinds of rollers of different sizes, which are convenient for switching between indoor and outdoor. The table is connected to the frame for easy pull-out use, while the seat can be folded for easy storage, but it is more complicated to use. Layout 2 changes the angle of the storage box to facilitate access to items. The rear wheels are large wheels, increasing the stability of outdoor movement, but may affect the indoor use. Layout 3's functional units were arranged more compactly to help save space. Small rollers facilitate indoor use but reduce the stability of outdoor use. The table board is located on the side of the frame to facilitate folding. In Layout 4, the height of the tabletop is conducive to standing use, but may be disturbed by the seat and storage box.

4.2.3. Analysis of product shape details

In this step, morphological charts were used to explore the possibilities of each functional unit. The research team diverged the six functional units in Figure 3 by referring to the APD information sheet of the walking aid and the design mood boards of other products (e.g., Pinterest, Behance, and other design inspiration sites). Several types of each functional unit were then obtained and constructed into a morphological chart (Table 4). In this chart, the permutations of the different types of functional units can generate up to $5 \times 4 \times 2 \times 5 \times 3 \times 3 = 2000$ design solutions.

4.2.4. Identify and visualize alternatives

The designers of the research team constructed three alternatives (Figure 4) based on the analysis of the advantages and disadvantages of the layout (Figure 3) and morphological details (Table 4) of the walker. Alternative 1 consisted of W3, H1, F1, S4, T3 and SB2. Alternative 2 consists of W4, H4, F2, S4, T3 and S1. Alternative 3 consists of W5, H2, F5, S4, T3 and S3. Finally, the CAD software RHINO 7.0 was used to create the visual 3D model and Keyshot 11 was used to apply color, material and lighting effects to the 3D model.

4.3. Phase III: evaluation

4.3.1. Establish evaluation structure model

The purpose of the evaluation phase was to select the optimal solution by calculating the priority of the alternatives. According to the PAPDM (Figure 1), the research team used seven OEIs from the 3D Hierarchical structure of preference factors for walking aids (Figure 2) as evaluation criteria to evaluate the three alternatives (Figure 4). The hierarchical structure of the AHP is shown in Figure 5.

4.3.2. Calculating weights

The decision matrix for the seven evaluation criteria was created by the research team through discussion using pairwise comparisons as shown in Table 5. The geometric mean method was used to calculate the priority of the evaluation criteria. The priorities in Table 5 are the normalized results of the geometric mean. It can be seen from the results that criterion X4 is the most important, followed by X6. In appearance design X1 has to be more important than X2 and X3. The lowest weight is given to X3. After the consistency calculation C.R. $= 0.043 < 0.1$ which passed the consistency test.

Decision matrix after obtaining the decision matrices for the seven evaluation criteria, the research team compared and scored all the alternative solutions in pairs based on each

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TABLE 2 The results of quantification theory type I.

OEIs	Category (CEIs)	Category score (Y1)	Category score (Y2)	Category score (Y3)	Category score (Y4)
X1	Pcc*			0.69405872	
	Z1			−0.694295449	
	Z2			−0.406247362	
	Z3			0.223237356	
X2	Pcc*		0.646210977	0.655606618	0.343514246
	Z4		−0.530776453	−0.105372975	−0.258472571
	Z5		−0.199680024	−0.328837861	−0.217732604
	Z6		0.246621294	0.454025079	0.038409297
	Z7		0.059145411	0.573367551	0.038476949
X3	Pcc*	0.411489841		0.445619759	
	Z8	−0.429115124		−0.166797472	
	Z9	−0.575073648		−0.321526021	
	Z10	−0.06400715		0.1059421	
	Z11	0.114413793		−0.23622149	
X4	Pcc*		0.783922799	0.844469589	0.751018827
	Z12		−0.22390375	−0.978848586	−0.308457724
	Z13		0.126382302	−0.354969171	−0.606445914
	Z14		−0.204260161	0.054010967	−0.412494032
	Z15		−0.710178192	−0.797802612	−0.457824878
	Z16		0.130849266	0.398199191	0.201549546
	Z17		−0.593295253	−0.031180255	−0.046436436
	Z18		1.467959923	1.952759209	−0.728790554
X5	Pcc*	0.529768572	0.83239666		
	Z11	0.380356751	−0.391423165		
	Z18	0.893470153	0.04029979		
	Z19	−0.345391974	−0.44752543		
	Z20	0.851427817	0.078373061		
	Z21	−0.179303222	1.224694654		
	Z25	−0.308202661	0.04029979		
X6	Pcc*	0.565455518			
	Z18	0.108979596			
	Z21	0.095287889			
	Z22	−0.628173088			
X7	Pcc*	0.467701856	0.65057751	0.665737262	0.674195586
	Z23	0.140021593	−0.030294467	−0.003485933	−0.454739207
	Z24	−0.675914602	−0.28965804	−0.574766544	−0.00462502
	Z25	−0.468641009	−0.121455953	0.192825793	−0.047351233
	Z26	0.032813053	0.761661107	0.492385408	0.470048427
Constant term		14.8	14.8	16.8	11.8
R		0.736	0.910	0.891	0.853
Coefficient of determination (R^2)		0.542	0.828	0.793	0.727

*represents the partial correlation coefficient.

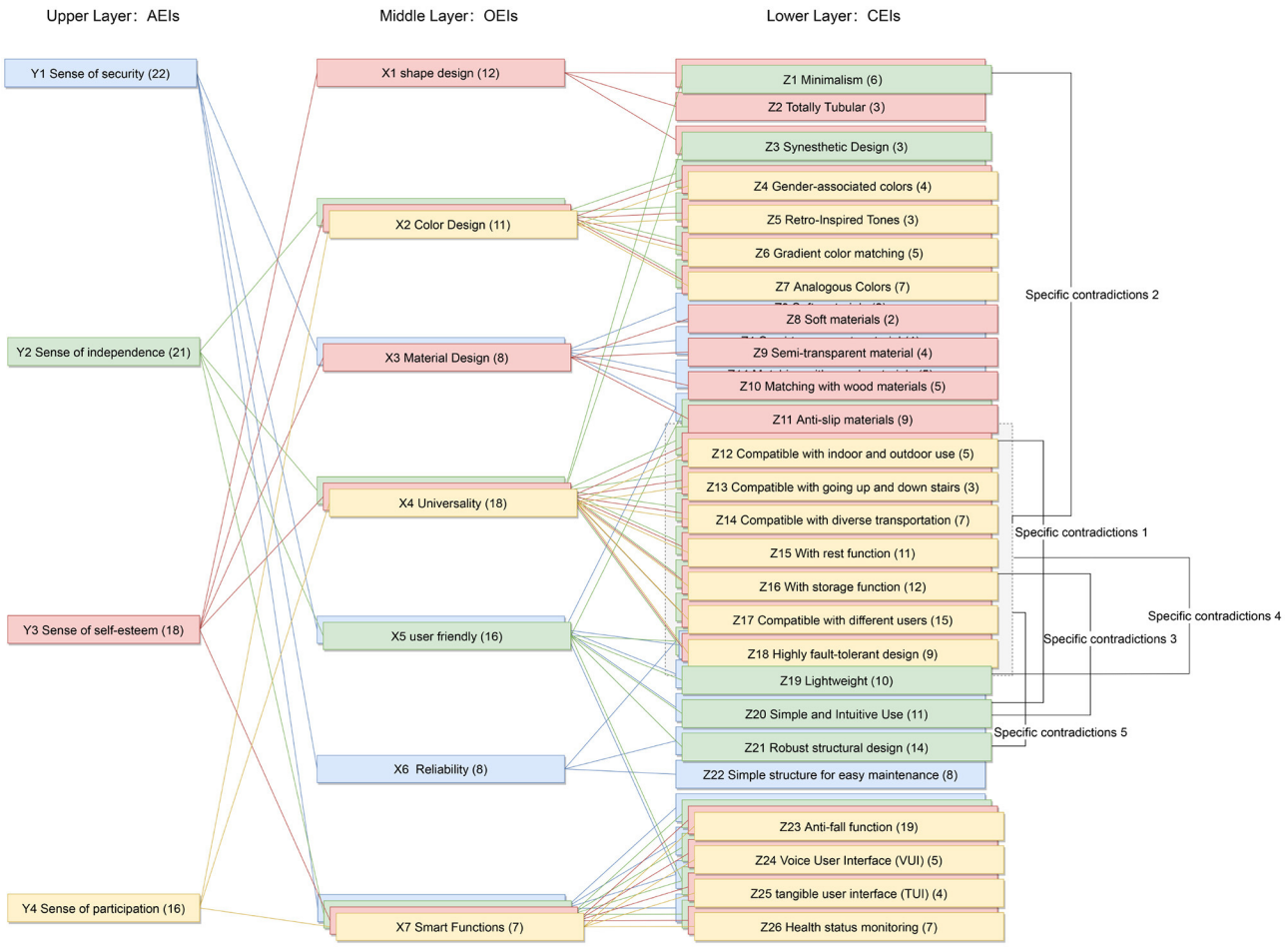


FIGURE 2
3D Hierarchical structure of preference factors for walking aids.

TABLE 3 Innovative guidelines generation process for walking aids.

Specific contradictions of walking aids	Type of contradiction	Engineering parameters	Separation principles	TRIZ invention principles	Innovation guidelines
Z12	TC	35	N/A	1, 15, 16, 34	Integration of different sizes of wheels
Z20		33			
Z1	PC	36	Conditional Separation	15, 34, 10, 9, 11	Modular design
Z14					
Z16	TC	10	N/A	36, 38	Height-adjustable storage box
Z20		22			
Z15	TC	1	N/A	3, 8, 15, 29	Partial replacement of accessories
Z19		35			
Z17	PC	13	Time Separation	15, 34, 10, 9, 11	Restrictive structural design
Z21					

evaluation criterion and subsequently created the decision matrix of alternative solutions as shown in Table 6. The results of the consistency calculation using Equation (1) showed that all alternatives passed the consistency test. This indicates that there are no logical problems with the weights of the 3 alternatives.

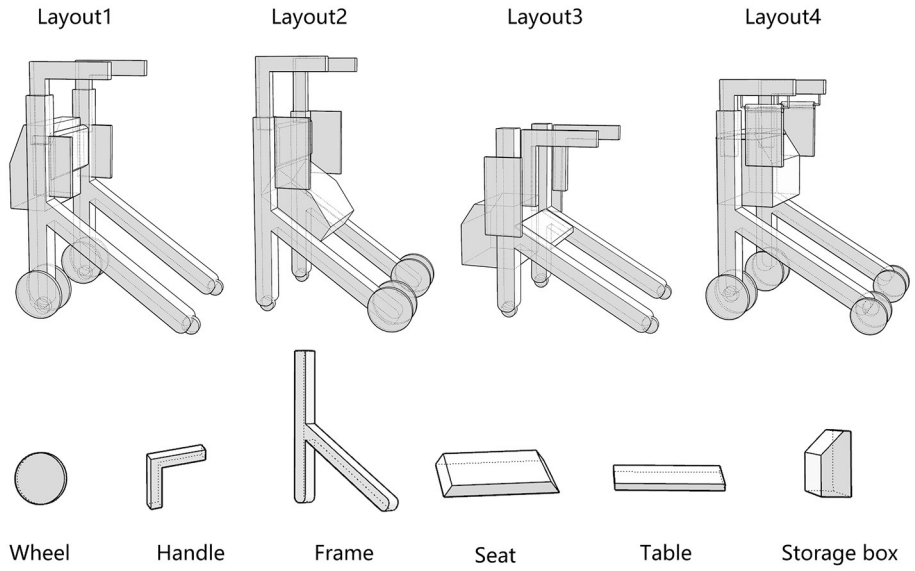


FIGURE 3
Several functional unit 3D layouts of walking aids.

The final priority values for the 3 alternatives are obtained by the weighted sum of the priorities of the evaluation criteria and the priorities of the alternatives. Table 5 shows the weight matrix β of the evaluation criteria.

$$\beta = [0.154\ 0.075\ 0.030\ 0.340\ 0.115\ 0.213\ 0.072]$$

The weight matrix α for the 3 alternatives can be obtained from Table 6.

$$\alpha = \begin{bmatrix} 0.238 & 0.196 & 0.311 & 0.163 & 0.163 & 0.311 & 0.196 \\ 0.136 & 0.311 & 0.493 & 0.540 & 0.297 & 0.196 & 0.311 \\ 0.625 & 0.493 & 0.196 & 0.297 & 0.540 & 0.493 & 0.493 \end{bmatrix}$$

The priority of the alternative is denoted by S. The result is calculated as follows.

$$S = \alpha \circ \beta = \begin{bmatrix} 0.238 & 0.196 & 0.311 & 0.163 & 0.163 & 0.311 & 0.196 \\ 0.136 & 0.311 & 0.493 & 0.540 & 0.297 & 0.196 & 0.311 \\ 0.625 & 0.493 & 0.196 & 0.297 & 0.540 & 0.493 & 0.493 \end{bmatrix} \circ \begin{bmatrix} 0.154 \\ 0.075 \\ 0.030 \\ 0.340 \\ 0.115 \\ 0.213 \\ 0.072 \end{bmatrix} = \begin{bmatrix} 0.216 \\ 0.341 \\ 0.443 \end{bmatrix}$$

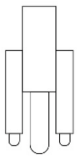
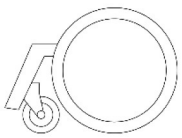
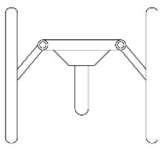
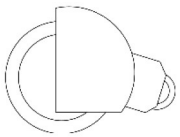
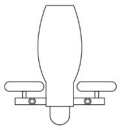
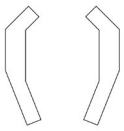
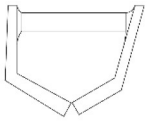
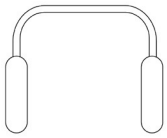
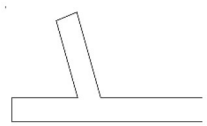
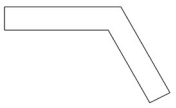
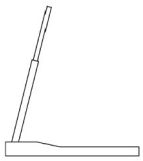
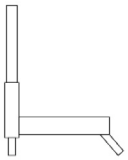
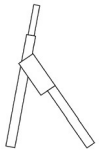
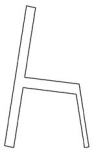
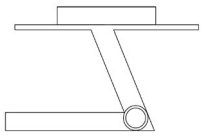
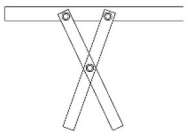
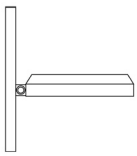
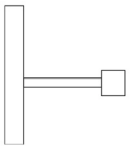
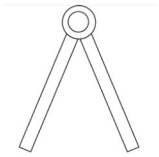
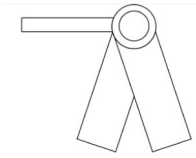
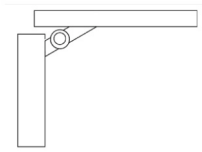
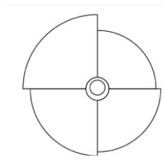
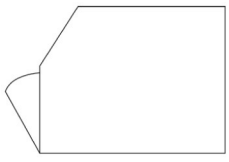
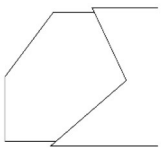
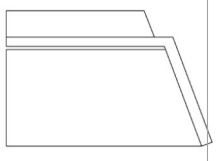
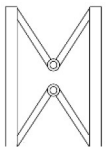
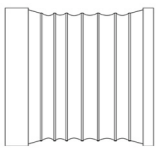
This calculation shows that the priority of the three alternatives of the walking aid is Alternative C > Alternative B > Alternative A, then Alternative 3 is the best solution. In addition, Figure 6 presents a radar chart of the weight values of the three walking aid alternatives across the seven evaluation criteria in this study. The performance of each alternative on each evaluation criterion dimension is intuitively shown.

5. Discussion

The first objective of this study was to identify a suitable method to extract the factors of preference for APs among the older adults as well as other users. The process was based on Miryoku engineering theory, integrating universal design (170) and contradiction analysis (171) from TRIZ based on EGM. Following the traditional EGM process (84), a preference factor structure for multi-user group was created (Figure 2). The advantages of EGM are twofold: first, it not only extracts the objective preferences of users for APs, but also explores the affective preferences behind these specific factors. Compared to similar affective calculation methods such as Kansei engineering (KE) (82) and Kano (172), EGM is easier to operate and effective. Secondly, EGM yields results as a visual cognitive structure that facilitates the enhancement of human thinking (173, 174). It is important to note here that the results of EGM are closely related to participants selection. These results may be influenced by the number of participants, their status, age, experience, etc. Using the judgmental sampling method (175) and involvement theory (168) used in Section 4.1.2 of this paper to select EGM participants is a suggested way.

Compared with traditional EGM methods (83, 87, 99), the improved EGM in this study has several advantages. Firstly, UD theory (170) was considered in the EGM process. The user preference extraction process for Aps involves a wider range of interviewees, including more stakeholders. The aim was to meet the needs of different users through universal design, thereby reducing the abandonment rate of APs and promoting active aging (12). Traditional EGM only interviews target users and pays less attention to the preferences of potential or non-target users, which is contrary to the trend of weakening the targeted development of Aps (6, 60). Secondly, this study added contradiction analysis to the traditional EGM, aiming to provide a basis for innovative

TABLE 4 The morphological chart of walking aids.

Function units	Type 1	Type 2	Type 3	Type 4	Type 5
Wheel (W)	 (W1) Sliding	 (W2) Rotating	 (W3) Folding	 (W4) Semi-wrapped	 (W5) Flipped
Handle (H)	 (H1) Bracket-shaped	 (H2) Polygonal	 (H3) Chamfered	 (H4) Branch-shaped	 (H5) obtuse angle
Frame (F)	 (F1) Acute angled	 (F2) Right-angled	 (F3) Branch-shaped	 (F4) Trapezoidal	 (F5) H-shaped
Seat (S)	 (S1) Z-shaped	 (S2) X-shaped	 (S3) Y-shaped	 (S4) Folded	 (S5) Pull-out
Table (T)	 (T1) Folio	 (T2) Revolving	 (T3) flipped	 (T4) Semi-wrapped	 (T5) Rolled up
Storage box (SB)	 (S1) Polygonal	 (S1) Vertical stack	 (S1) Horizontal stacking	 (S1) Bi-directional folding	 (S1) Bellow

ideation. This was also due to the inclusion of universal design. The expansion of the user group leads to greater differences in user preferences and more obvious contradiction between preference factors. In previous related studies (84, 176, 177), the contradiction relationships between lower items (CEI) in EGM were rarely discussed. Chen (95) used the CIP measurement method to divide EGM interviewees into three groups and found cognitive differences among users with different levels of participation. Personality differences (87) and user background differences (178) have also been discussed in previous EGM studies. However, these studies did not mention how to resolve these differences or contradictions in the design process. Thirdly, the research team used 3D charts to visualize the multi-level cognitive structure of interviewees. From Figure 2, it can be seen that the same OEIs and CEIs may be associated with multiple AEIs, so different colors are used to represent the preference factors included in each AEI in the

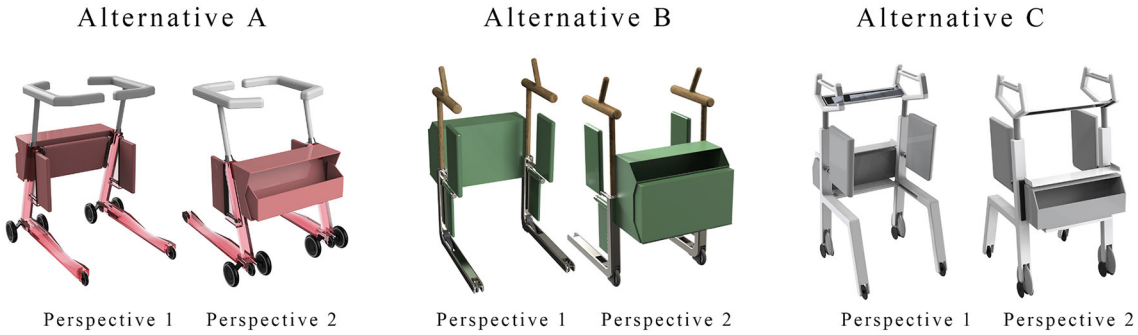


FIGURE 4
Three alternatives for the walking aids.

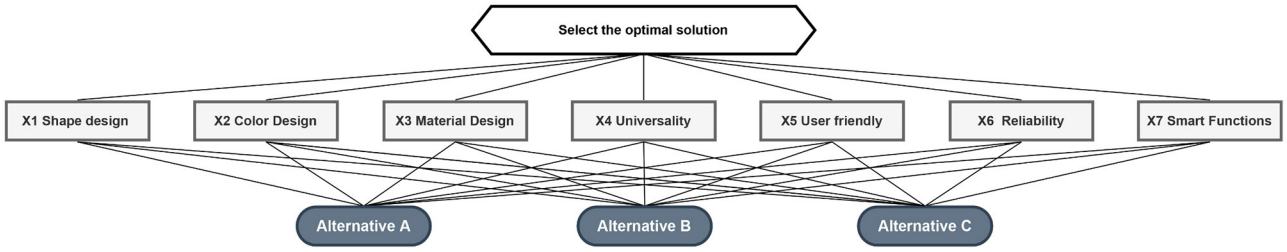


FIGURE 5
The evaluation structure model of walking aids.

EGM chart. Although some scholars have developed visualization tools for EGM (173, 174), the 3D EGM chart was more intuitive and clear than the 2D EGM chart in previous studies.

The second purpose of this study was to develop an integrated design framework for APD that aligns with the preferences of older adults. The PAPDM (Figure 1) was the result based on this purpose. At the core of this model is divergent and convergent thinking, which is similar to classical design thinking models such as the double diamond model (179). The advantages and possible roles of PAPDM are as follows:

First, PAPDM will help solve the difficulties of information collection in the APD process. This is specifically achieved through the APD information chart constructed during the definition phase. As can be seen in Section 4.1.1, in the first stage, different types of databases were used to collect a wide range of walking aids (Table 1). The images and textual information in the table were the source of representative samples for EGM. Design inspiration was also provided for the implementation of TRIZ, FSM, and Morphological Charts in the second phase. Compared to traditional data collection and sample preparation processes, using this integrated graphic and textual information table helps designers reduce the difficulties of repeatedly searching long-term memory (LTM) and generate more design inspirations. APD information chart (Table 1) produced similar effects to case-based reasoning (CBR) (180) and design heuristics (DHs) (181), as also demonstrated in the research results of Lee et al. (182) and Hwang and Park (72).

Second, PAPDM can clearly elicit the perceptions of user groups such as older adults regarding APs. This is achieved through a hybrid approach of EGM and QTT1. Section 4.1.2 shows the detailed EGM process. On the left side of Figure 2, it can be seen that the emotional preference factors of older adults focus on security, independence, self-esteem, and involvement, which supports the policy recommendations of the Active Aging Framework (12). In the middle layer of Figure 2, X1, X2 and X3 are product appearance attributes while X4-X7 embody the product function attributes. Section 4.1.3 shows the implementation process of the QTT1, and the results in Table 2 show the spatial layout of OEIs and CEIs in different AEIs. The high value of Coefficient of de-termination (R^2) indicates that the result explains most of the data, which is similar to previous studies (96, 183). It is worth reflecting that the negative values in the scores of CEIs are often not well interpreted and used, which is worth exploring in future studies.

Third, PAPDM makes the conceptualization process of APD transparent. In previous research (83, 96), the results of EGM and QTT1 were rarely further utilized, especially in a progressive and transparent way to generate concepts. In the second stage of PAPDM, TRIZ was used to connect the results of QTT1. The five innovation guidelines proposed in the ideation phase (Table 3) were all functional or structural innovation strategies used to meet multiple needs. This result was also demonstrated in Zhang et al. (126) study. This may be related to the principle of invention chosen by the research team. Each contradictory pair contained

TABLE 5 Decision matrix for 7 evaluation criteria.

	X1	X2	X3	X4	X5	X6	X7	Priorities
X1	1	3	5	0.333	2	0.5	2	0.154
X2	0.333	1	3	0.2	0.333	0.5	2	0.075
X3	0.2	0.333	1	0.143	0.2	0.167	0.333	0.030
X4	3	5	7	1	3	2	4	0.340
X5	0.5	3	5	0.333	1	0.5	1	0.115
X6	2	2	6	0.5	2	1	4	0.213
X7	0.5	0.5	3	0.25	1	0.25	1	0.072

TABLE 6 Decision matrix of 3 walking aid alternatives under 7 evaluation criteria.

	A	B	C	Priorities	Criterion	C.R.	Consistency check
A	1	2	0.333	0.238	X1	0.016	accept
B	0.5	1	0.25	0.136			
C	3	4	1	0.625			
A	1	0.5	0.5	0.196	X2	0.046	accept
B	2	1	0.5	0.311			
C	2	2	1	0.493			
A	1	0.5	2	0.311	X3	0.046	accept
B	2	1	2	0.493			
C	0.5	0.5	1	0.196			
A	1	0.333	0.5	0.163	X4	0.008	accept
B	3	1	2	0.540			
C	2	0.5	1	0.297			
A	1	0.5	0.333	0.163	X5	0.008	accept
B	2	1	0.5	0.297			
C	3	2	1	0.540			
A	1	2	0.5	0.311	X6	0.046	accept
B	0.5	1	0.5	0.196			
C	2	2	1	0.493			
A	1	0.5	0.5	0.238	X7	0.046	accept
B	2	1	0.5	0.136			
C	2	2	1	0.625			

multiple invention principles, and the research team obtained a total of 20 invention principles each of which could be specified as multiple innovation guidelines. The final five innovation guidelines were selected on the basis of universal design principles, and the versatility of TRIZ in generating ideas has been demonstrated in a wide range of studies (146, 171, 184). Section 4.2.2 and section 4.2.3 are both about the form divergence of the walking aid. The former analyzes the layout of each functional unit of the walker the latter considers the diversity of design details. In previous FSM studies (185), the layout of functional units was mostly arranged in two dimensions with words, symbols and geometric shapes. 3D layout (Figure 3) facilitates the diversity of solutions. The morphological chart of the walking aid (Table 4) shows that each functional unit was diverged into five unique form details. However, how to converge the ideal solution among the large number of details has not been agreed in previous studies (141, 147) and deserves to be discussed in future studies.

In addition to the advantages mentioned above, an interesting finding is that the AHP methods in the evaluation phase can be well compatible with EGM. They are both based on a hierarchical analysis method. The evaluation criteria in the AHP just correspond to the OEIs in the EGM results. The results of Lu et al. (134) and Kang et al. (186) study also prove this finding. In the evaluation phase, the evaluation criteria were the

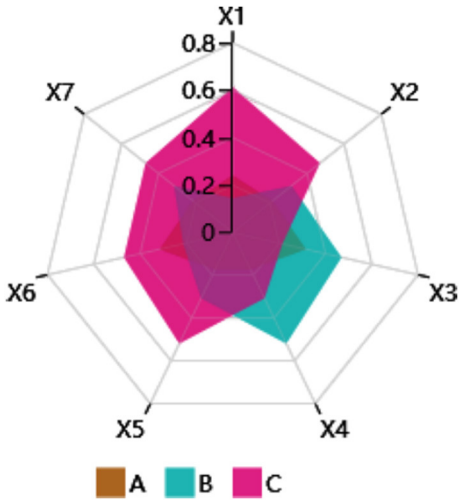


FIGURE 6
The radar chart of walking aids alternatives.

seven OEIs in the EGM. The priorities of these evaluation criteria (Table 5) are generally consistent with the pcc values demonstrated in the QTT1 results (Table 2). For example, the pcc value of X4 (generalizability) in Table 2 is much larger than the other OEIs. The priority of X4 (0.34) in Table 5 also ranks first. This proves the consistency of the QTT1 and AHP algorithms. In addition, the AHP evaluation criteria can be subdivided into multiple sub-criteria and the evaluation criteria and solution priorities can be used to obtain more accurate results through group decision making. Additional studies are needed to consider these variables.

6. Conclusions

This paper was conducted to address two research questions. The first research question addressed how to capture the preference factors of a multi-user group, primarily consisting of older adults, toward assistive products. The research team integrated EGM, UD, contradiction identification, and QTT1 to extract and analyze the preference factors of the user group, including their relationships and weights. The second research question focused on establishing and validating an effective Assistive Product Design (APD) framework based on Universal Design principles. We introduced a preference-based assistive product design framework called PAPDM and demonstrated its detailed process through a case study involving the design of a walking aid. The framework comprised three major stages. The first stage, the definition phase, addressed the first research question. In the second stage, we employed the TRIZ contradiction matrix and the 40 Inventive Principles to propose design guidelines by resolving contradictions within the assistive product design. We explored various solution alternatives using FSM and morphological charts to generate more suitable alternative designs. In the third stage, we utilized the Analytic Hierarchy Process (AHP) to evaluate the alternative designs and make decisions. Both PAPDM and the walking aid solution C from the case study are currently undergoing patent applications for invention and utility models. The case study demonstrated that the APD information chart is an effective way to gather information, compensating for the limited information provided by older adults during interviews.

This project marked the first combination of EGM and TRIZ, and we discovered that these two methods effectively complement each other. They not only enhanced the role of EGM in proposing design strategies but also provided a problem identification approach for TRIZ. TRIZ, in turn, offered innovative guidelines for FSM and morphological charts. Furthermore, PAPDM enhanced the applicability of UD theory in assistive product design to a certain extent.

One limitation of this study was the small number of interviewees, which may have resulted in a limited breadth of coverage in the interview results. User preferences also change with societal development and the iterative process of assistive product design, necessitating regular surveys of larger target user groups. Additionally, the invention principles of TRIZ are abstract and broad, so the elimination process of contradictions is influenced by variations in the quantity and quality of designer knowledge. Further research may be needed to impart disciplinary attributes to the invention principles of TRIZ. Lastly, the evaluation criteria for alternatives were single-layered in structure, and in the future, different sub-criteria could be listed to enable a more accurate comparison of alternative details. Despite these limitations, the research findings in this paper provide a logically robust and actionable framework for fostering innovation in assistive products. This study holds practical significance in improving the independence and social participation of older adults.

Data availability statement

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

Ethics statement

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

Author contributions

BZ and MM contributed to conception and design of the study. MM provides the core research methodology in the manuscript. BZ organized the database and performed the experiment. BZ and ZW performed the statistical analysis and wrote the draft of the manuscript. ZW visualized the results of the study. All authors contributed to manuscript revision, read, 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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Determinants of active aging and quality of life among older adults: systematic review

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Introduction: Population demography across the globe shows an increasing trend in the aging population due to better healthcare, improved nutrition, advanced health-related technology, and decreased fertility rate. Despite these advancements, there remains a knowledge gap in understanding the association between active aging determinants and quality of life (QoL) among older adults, particularly within diverse cultural contexts, which has not been adequately explored in previous research. Therefore, understanding the association between active aging determinants and QoL can help policymakers plan early interventions or programs to assist future older adults in both aging actively and optimizing their quality of life (QoL), as these two factors have a bidirectional relationship.

Objective: This study aimed to review evidence regarding the association between active aging and quality of life (QoL) among older adults and to determine the most widely used study designs and measurement instruments in studies conducted between 2000 and 2020.

Methods: Relevant studies were identified by a systematic search of four electronic databases and cross-reference lists. Original studies examining the association between active aging and QoL in individuals aged 60 years or older were considered. The quality of the included studies and the direction and consistency of the association between active aging and QoL were assessed.

Results: A total of 26 studies met the inclusion criteria and were included in this systematic review. Most studies reported a positive association between active aging and QoL among older adults. Active aging had a consistent association with various QoL domains including physical environment, health and social services, social environment, economic, personal, and behavioral determinants.

Conclusion: Active aging had a positive and consistent association with several QoL domains among older adults, backing the notion that the better the active aging determinants, the better the QoL among older adults. Considering the broader literature, it is necessary to facilitate and encourage the active participation of older adults in physical, social, and economic activities for the maintenance and/or improvement of QoL. Identifying other possible determinants and enhancing the methods to improve those determinants may help improve the QoL among older adults.

KEYWORDS

active aging, quality of life, older adults, health, participation, security

Introduction

Population demography across the globe shows an increasing trend in the aging population due to better healthcare, improved nutrition, advanced health-related technology, and decreased fertility rate (1). By the year 2050, the global population of older adults is expected to increase by approximately 20.6%, resulting in an estimated 2 billion older adults worldwide. Most of these older adults will live in low- and middle-income countries [LMICs; (2)]. Due to this rapid demographic transition, there will be a potential shortage of the productive young population in the coming decades (2). Therefore, it is essential to develop strategies by which older people can be actively engaged to promote their wellbeing and that of their families. In contrast to previous studies in this area (3–5), which primarily focused on specific disease conditions or were conducted in developed regions, our study adopted a comprehensive approach to examine the association between active aging determinants and quality of life (QoL) among community-dwelling older adults from diverse cultural contexts. This broader perspective provides valuable insights for early intervention programs and policies aimed at enhancing the lives of older adults (6, 7).

The novel findings of our study are crucial for understanding the various factors that contribute to QoL in older adults across different cultural settings, thus supporting their wellbeing and helping them age actively and healthily. By extending our analysis beyond specific health conditions and incorporating a wider range of geographical regions, we hope to inform the development of more inclusive and effective policies and interventions for older adults around the world. The World Health Organization (WHO) as part of its Aging and Life Course Program has developed the "Active aging: a policy framework" to address this problem (8). The framework intends to inform and guide discussion and formulation of action plans that foster healthy and active aging.

The concept of active aging was defined by the WHO as "the process of optimizing opportunities for health, participation, and security to enhance quality of life as people age" (9). Active aging emerges as a strategy to achieve QoL, permeated and influenced by six determinants: physical environment, health and social services, social environment, economic, personal, and behavioral determinants (10). This multidimensional definition implies that this concept intersects with others, such as productive aging, healthy aging, and successful aging (11–13).

Although active aging and QoL have some overlap, by definition, active aging is considered a dynamic process, whereas the QoL is a "state of being" (9). A study has noted that elements that compose the active aging index also relate to the elements that define life satisfaction/life happiness as measured for QoL (6). Furthermore, another study, using a sample from 27 European countries, examined QoL among older adults as a subset of active aging (7).

Within this broad framework of active aging and QoL, engaging in social activities, along with better physical health, financial condition, and security, are the essential aspects of QoL as defined by older adults themselves (14, 15). The concept of QoL is at times used conversely with active aging but is mainly considered as an outcome or the proxy measure of active aging (1, 7, 16–18).

Previous studies have reported the association of QoL with regard to diseases and clinical conditions among older adults (3–5), but none have investigated the association of active aging determinants with QoL. In this study, we aimed to fill the knowledge gap by investigating the association between active aging determinants and quality of life (QoL) among older adults. Our research stands out from previous studies that mainly focused on the association of QoL with diseases and clinical conditions among older adults (3–5). By examining the association between active aging determinants and QoL, our study offers a more comprehensive understanding of these factors and their role in promoting active aging and better QoL for older adults. Understanding the association of active aging determinants and QoL may help policymakers plan an early intervention or program to assist the future older adult in aging actively by optimizing their quality of life. Ultimately, this will help in the comprehensive support of the aging population in physical, mental, social, and financial wellbeing. Thus, this study aims to demonstrate the association of active aging with QoL, describing the need for more all-inclusive and broader measures designed to incorporate these unique factors influencing healthcare, health outcomes, longevity, and overall QoL in older age.

Methodology

Protocol and registration

This systematic review of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines (19) and the study protocol were registered in the International Prospective Register of Systematic Reviews (PROSPERO): CRD42020186740.

Eligibility criteria

Only studies published in the English language were considered in this review. Studies were included based on a series of predefined inclusion and exclusion criteria as follows:

Inclusion and exclusion criteria

The study used the following inclusion criteria: (i) published original articles that assessed the association between active aging (AA) components and QoL domains; (ii) studies published between 1 January 2000 and 31 July 2020; (iii) having individuals aged 60 years or older as the study sample; and (iv) interventional, cross-sectional, and longitudinal study designs. For QoL assessment, we considered studies that used self-reported QoL questionnaires and wellbeing scales containing QoL or Health-Related Quality of Life (HRQoL) domains (life satisfaction, wellbeing, and self-rated health) and specific domains that include QoL or HRQoL (physical, cultural, social, psychological, mental, and spiritual domains). In addition, we included studies that utilized other relevant QoL assessment tools, such as CASP, SF EQ5D, and VAS, due to their established validity in evaluating active aging and QoL. We decided

not to limit the study search to those that assess QoL using only generic instruments (WHOQoL-100 or SF-36). As a result, we also included key intervention and cohort studies that assessed the association between elements of AA and QoL domains.

Search strategy

We searched for relevant articles from various electronic databases, including MEDLINE/PubMed, EMBASE and Cochrane via OVID and Open Gray, LILACS, and CINAHL. We used keywords for active aging (health, participation, and security) and the population of interest (geriatrics, older adults, elderly, aged people, and seniors), in combination with the keyword for QoL (quality of life). Keywords were combined using the Boolean operators "AND" and "OR". All identified articles were screened independently by two reviewers (RM and SS) (Appendix 1).

Data selection and collection process

The identified articles from the search were screened by two independent researchers/authors (RM and SS). At first, titles and abstracts of identified articles were assessed, and then eligible articles with full texts were retrieved and screened in full against the eligibility criteria mentioned above. All disagreements that arose were solved via discussion with a third reviewer (PKM, DM, or TTS). A flowchart detailing the study inclusion and exclusion process is included (Figure 1).

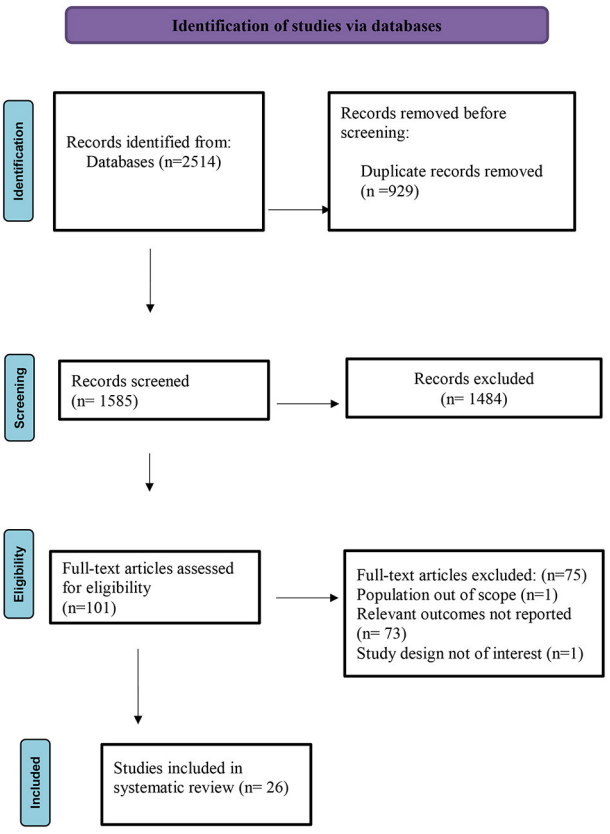

FIGURE 1
PRISMA flow chart for the inclusion and exclusion process.

Data extraction

Data were independently extracted by two reviewers (RM and SS) using a standardized data extraction template designed for this purpose. The following data and information were extracted from each of the included studies: country, study setting, sample type, and size, participants' age and gender, QoL measurement instruments (both generic and specific scales related to health, security, and participation), and active aging measures/definition. Disagreements at this stage were also solved via discussion with a third party/reviewer where necessary.

Quality assessment

The quality of included studies was examined, independently, by two authors (RM and PK) using the Newcastle–Ottawa Quality Assessment Scale (NOS) of cross-sectional and cohort studies (20). Here, we determined the quality of selection, comparability, exposure, and outcome of each study participant, using a scoring system (maximum 9 points). The qualities of included studies were categorized into three: (1) high (score of 7–9); (2) moderate (score of 4–6); and (3) low (score of 0–3) qualities.

The Joanna Briggs Institute (JBI) Critical Appraisal Tool (21) was used to examine the methodological quality of interventional studies and the extent to which a study addressed the possibility of bias in its design, conduct, and analysis. The qualities of assessed studies were divided into three categories: (+) Yes implying low-risk bias; (?) unclear; and (–) No, implying high-risk bias. Disagreements were resolved through discussion to reach the final agreed score.

Results

Study selection process

Figure 1 presents the study selection process, which was divided into four key stages:

(i) ***Identification***: In July 2020, a database search was done through Central, Embase, Medline via OVID (2,502 articles), CINAHL (3 articles), LILAC, and Open Gray (5 articles), and bibliographic search of systematic literature reviews (SLRs) (4 articles). Thus, the initial search yielded 2,514 articles identified from the online databases. However, 929 were removed because they were duplicates.

(ii) ***Screening***: In total, 1,585 titles and abstracts were screened for eligibility. A total of 1,484 studies were removed because they did not meet the eligibility criteria such as population out of scope, intervention not of interest, relevant outcomes not reported, and study design and publication type not of interest.

TABLE 1 Quality of studies assessed through the newcastle–ottawa quality assessment scale.

References	Selection				Comparability		Outcome			Total quality score
	Representativeness of exposed cohort	Selection of non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at the start of the study	Adjusted for the most important risk factors	Adjusted for other risk factors	Assessment of outcome	Follow-up length	Lost to follow-up rate	
López-Ortega and Konigsberg (22)	1	1	1	1	1	0	1	1	0	7
Liu et al. (23)	1	1	1	1	0	0	1	1	0	6
Levasseur et al. (24)	1	1	1	1	0	0	1	1	0	6
Ramia and Voicu (7)	1	1	1	1	0	0	1	1	0	6
Puvill et al. (25)	1	1	1	1	1	1	1	1	0	8
Abdelbasset et al. (26)	1	1	1	1	0	0	1	1	0	6
Kim et al. (27)	1	1	1	1	1	0	1	1	0	7
Neri et al. (28)	1	1	1	1	1	0	0	1	0	6
Dahlberg and McKee (29)	1	1	1	1	1	1	0	1	0	7
Zhang et al. (30)	1	1	1	1	1	1	1	1	0	8
He et al. (31)	1	1	1	1	1	0	1	1	0	7
Ju et al. (32)	1	1	1	1	0	0	1	1	0	6
Choi et al. (33)	1	1	1	1	1	0	1	1	0	7
Onunkwor et al. (35)	1	1	1	1	0	0	1	0	0	5
Haider et al. (36)	1	1	1	1	0	0	1	1	0	6
Marques et al. (37)	1	1	1	1	0	0	1	1	0	6
Tavares et al. (38)	1	1	1	1	1	0	1	1	0	7
Top and Dikmetaş (39)	1	1	1	1	1	0	1	1	0	7
Park et al. (40)	1	1	1	1	1	0	1	1	0	7

(Continued)

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TABLE 1 (Continued)

References	Selection				Comparability		Outcome			Total quality score
	Representativeness of exposed cohort	Selection of non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at the start of the study	Adjusted for the most important risk factors	Adjusted for other risk factors	Assessment of outcome	Follow-up length	Lost to follow-up rate	
Bilgili and Arpaci (41)	1	1	1	1	1	0	1	1	0	7
Sampaio et al. (42)	1	1	1	1	1	1	1	1	0	8
Layte et al. (43)	1	1	1	1	0	0	1	1	0	6
Sewo Sampaio and Ito (44)	1	1	1	1	1	1	1	1	0	8
Guedes et al. (45)	1	1	1	1	1	0	1	1	0	7
Gureje et al. (46)	1	1	1	1	1	0	1	1	0	7

(iii) ***Eligibility***: At this stage, 101 full-text articles were assessed. Of these, 75 studies were excluded after a full-text review because the population was out of scope, relevant outcomes were not reported, and study design was not of interest.

(iv) ***Included***: In total, 26 studies were considered to be eligible for inclusion in this systematic review.

General characteristics of the studies

There were 22 cross-sectional, three longitudinal, and one quasi-experimental design studies—all studies composed exclusively of the older people (60 years or older) of both sexes (Table 2). Of the 26 studies, 14 studies were from seven Asian countries (China, India, Korea, Japan, Malaysia, Turkey, and Egypt). Two studies were conducted in the Latin American region (Brazil and Mexico) and four European regions (Austria, Ireland, UK, and Israel). One study each was conducted in Canada, Australia, and Nigeria.

Two contexts of the living arrangement were considered; community-based dependent older people and older people living in residential aged-care facilities. Eighteen studies included community-dwelling participants (22–26, 31, 32, 36–38, 41–48) and four studies included participants from residential aged care facilities (30, 34, 35, 39), while four studies did not report the kind of living arrangement (28, 29, 33, 40).

Quality of studies

The qualities of cross-sectional and longitudinal studies were assessed through the NOS scale (Table 1). Based on the proposed cutoff points, 15 studies were classified as high-quality (22, 25, 28–31, 33, 38–42, 44–47) and 10 studies of medium quality (23, 24, 26, 28, 32, 35–37, 43, 48). The Joanna Briggs Institute (JBI) was used to evaluate the quality of the quasi-experimental study and scored 8/9 (88%) low risk of bias (34).

Table 2 summarizes the instruments used to measure the QoL in the selected 26 studies. The concept of AA was measured, considering the three pillars of AA: participation, health, and security. The current study analyzed the active aging of the older population through their level of participation in physical, social, and cultural leisure activities about their socio-demographic characteristics and QoL dimensions in old age. In addition to participation, the health and security statuses have been also investigated in relation to QoL among older adults. The most widely used questionnaire to assess QoL is the World Health Organization Quality of Life Assessment–Module for Older Adults (WHOQoL-Old) (8 studies) (30, 36, 38, 39, 41, 42, 44, 45), followed by the WHOQOL–Abbreviated Version (WHOQoL-Bref) (6 studies) (35, 36, 42, 44, 46, 48) and the Short Form-36 (SF-36) (5 studies) (22, 23, 30, 31, 34). The European Quality of Life-5 Dimension (EQ-5D) (26, 40), Control, Autonomy, Self-Realization, and Pleasure (CASP-19) (28, 43), and visual analog scale (VAS) (32, 33) were used in two studies each. The following instruments were used in one study each: The Satisfaction with Life Scale

TABLE 2 Summary study characteristics.

References	Countries	Setting	Study design	Sample size (N)	Female %	QoL instruments
López-Ortega and Konigsberg (22)	Mexico	Community-dwelling	Cross-sectional	295	43.5	SF-36
Liu et al. (23)	China	Community-dwelling	Cross-sectional	442	58.6	SF-36
Levasseur et al. (24)	Canada	Community-dwelling	Cross-sectional	155	60	SWLS
Ramia and Voicu (7)	India	Community-dwelling	Cross-sectional	160	100	WHOQOL-BREF
Puvill et al. (25)	Europe and Israel*	Community-dwelling	Cross-sectional	66,561	55.9	CASP-12
Abdelbasset et al. (26)	Egypt	Community-dwelling	Cross-sectional	184	29.9	EQ-5D
Kim et al. (27)	South Korea	Community-dwelling	Cross-sectional	517	89.2	SF-12
Neri et al. (28)	Brazil	Not reported	Longitudinal	7,651	53.2	CASP-19
Dahlberg and McKee (29)	UK	Not reported	Cross-sectional	1,255	61.8	WHO-5
Zhang et al. (30)	China	Residential aged care facility	Cross-sectional	1,369	60	WHOQOL-OLD, SF-36
He et al. (31)	China	Community-dwelling	Cross-sectional	2,644	59.19	SF-36
Ju et al. (32)	South Korea	Community-dwelling	Longitudinal	340	36.5	VAS
Choi et al. (33)	Korea	Not reported	Longitudinal	7,096	57.1	VAS
Rugbeer et al. (34)	Australia	Residential aged care facility	Quasi-experimental design	100	79	SF-36
Onunkwor et al. (35)	Malaysia	Residential aged care facility	Cross-sectional	203	32.5	WHOQOL-BREF
Haider et al. (36)	Austria	Community-dwelling	Cross-sectional	83	86	WHOQOL-BREF, WHOQOL-OLD
Marques et al. (37)	Brazil	Community-dwelling	Cross-sectional	1,197	64.5	CASP-16
Tavares et al. (38)	Brazil	Community-dwelling	Cross-sectional	1,691	63.7	WHOQOL-OLD
Top and Dikmetaş (39)	Turkey	Residential Aged care facility	Cross-sectional	120	36.66	WHOQOL-OLD
Park et al. (40)	South Korea	Not reported	Cross-sectional	229,226	2.719	EQ-5D
Bilgili and Arpaci (41)	Turkey	Community-dwelling	Cross-sectional	300	48.3	WHOQOL-OLD
Sampaio et al. (42)	Japan	Community-dwelling	Cross-sectional	465	NR	WHOQOL-BREF, WHOQOL-OLD
Layte et al. (43)	Ireland	Community-dwelling	Cross-sectional	6,279	NR	CASP-19
Sewo Sampaio and Ito (44)	Japan	Community-dwelling	Cross-sectional	465	48.6	WHOQOL-BREF, WHOQOL-OLD
Guedes et al. (45)	Brazil	Community-dwelling	Cross-sectional	1,204	53.57	WHOQOL-OLD
Gureje et al. (46)	Nigeria	Community-dwelling	Cross-sectional	2,152	NR	WHOQOL-BREF

NR, Not reported; *27 European countries.

TABLE 3 Similarities and differences of the questionnaires/instruments used.

Questionnaire	Determinants of active aging					
	Personal	Behavioral	Social environment	Health and social services	Physical environment	Economic
WHOQoL–OLD	√	√	√	√	√	√
WHOQoL–BREF	√	√	√	√	√	√
CASP-19	√	√	√			
CASP-16	√	√	√			
CASP-12	√	√	√			
SF-36	√	√	√			
SF-12	√	√	√			
EQ5D	√	√	√			
VAS	√	√				
SWLS	√					
WHO-5	√					

(SWLS) (24), CASP-12 (25), SF-12 (47), WHO-5 (29), and CASP-16 (37).

The selected studies in the present systematic review used different questionnaires for assessing active aging. We observed that the questionnaire assessed different determinants of active aging. For example, the WHOQoL–OLD and WHOQoL–BREF assessed the personal, social, behavioral, environment, health and social services, physical environment, and economic aspects of aging; while CASP-12, CASP-16, CASP-19, SF-12, SF-36, and EQ5D measured the three aspects of active aging, namely personal, behavioral, and social aspects. Similarly, VAS was used to assess the personal and behavioral aspects and SWLS and WHO-5 measured personal aspects only (Table 3).

Association of active aging determinants and QoL

Table 4 summarizes the key findings on the association between elements of AA and QoL domains. Various instruments were used to ascertain QoL scores, thus allowing a wide variety of QoL domains to be evaluated in the analyzed studies. The most examined QoL domains included physical health, mental health, functional capacity, psychological, emotional, social relationships, environment, pain, overall health, general QoL, and vitality concerning social participation and engagement in reading, art, and leisure activities.

Six out of six studies using WHQOL-Bref showed that social participation and other activities such as reading, art, and physical activities significantly influence the QoL (35, 36, 42, 44, 46, 48). Seven out of eight studies using WHOQOL-Old demonstrated the consistent positive influence of activities including social participation, participating in art activities, reading, etc. on the QoL (30, 38, 39, 41, 42, 44, 45). Three out of five studies employing SF-36 showed that social or community participation is a relevant factor influencing the QoL (23, 30, 31). Two studies using CASP-19 showed that social participation and interaction significantly influence QoL (28, 43).

Discussion

This systematic review synthesized evidence on the investigation of the association of active aging with QoL determinants among older adults. To date, most of the studies targeting QoL are focused mainly on clinical conditions, and thus the association of active aging determinants and QoL is uncharted. Our systematic review shows that different types of assessment tools have been used for the evaluation of QoL considering different components of AA, which varied with sex, settings, and study design, and resulted in a wide variation in association of QoL and active aging determinants. Due to the importance of AA, as it could interfere with personal as well as relatives' life, the understanding of determinants that affect AA is essential. This review has enhanced our knowledge of active aging in context to the quality of life that may prove crucial in understanding how the QoL can be maintained simultaneously with active living among older adults. In summary, our study supports the notion that the better the active aging determinants, the better the QoL among older adults.

Among the selected 26 studies in the current systematic review, QoL was assessed using different tools. We observed that the use of different QoL questionnaires resulted from the inclusion of different active aging determinants (Table 4) and therefore, variable determinants have been studied in different studies. For instance, some studies investigate the influence of personal determinants only, while some consider physical factors and some considered multiple factors such as physical activity, social participation, and mental health. Although this discrepancy among the investigated determinants is due to the use of variable questionnaires, the

TABLE 4 Association of active aging determinants and quality of life.

References	Scale for QOL	QoL determinants	Results
López-Ortega and Konigsberg (22)	SF-36	Personal factors, behavioral determinants, determinants of social environment	Measure: β-coefficient [95% CI] Physical functioning ($P < 0.01$), Vitality ($P < 0.001$) • Marital status: Widowed (compared to single and married) • Physical functioning $p < 0.05$, role limitations owing to physical-health problems $p < 0.01$, role limitations because of emotional problems $p < 0.01$, vitality $p < 0.05$, energy and fatigue, mental-health (psychological distress and emotional wellbeing) $p < 0.05$, social functioning $p < 0.01$, bodily pain $p < 0.05$ • Financial status: Poor (compared to good and fair financial status) • $p < 0.05$ in physical functioning, role limitations because of physical health problems, role limitations owing to emotional problems, vitality, energy and fatigue, mental health comprising of psychological distress and emotional wellbeing, social functioning, bodily pain, and *general health perception* • Concerning living arrangements and social support, the number of contacts with family members and close friends affected only physical function ($p < 0.01$), vitality ($p < 0.05$), mental health (psychological distress and emotional wellbeing) $p < 0.01$, and social functioning $p < 0.01$ • Chronic diseases consistently had lower scores in all SF-36 dimensions, although only physical functioning ($p < 0.05$) and vitality ($p < 0.01$) had significant statistical differences • Household members living with the respondent and occupation did not affect the 8 domains of the SF-36. • Except for the general health domain ($p < 0.01$), the presence of chronic diseases did not affect estimated models on HRQoL domains.
Liu et al. (23)	SF-36	Personal factors, behavioral determinants, determinants of social environment	• The mental component summary (MCS) encircles the domains of Mental health, role limitations because of emotional problems, social functioning, as well as vitality. • In contrast, the physical component summary (PCS) encompasses a general perception of health, bodily pain, role limitations owing to physical problems, and physical functioning. • Older adults (married/widowed individuals) had significantly greater MCS and PCS scores compared to the never-married or divorced ($P < 0.05$). • Lower MCS scores were found among those who had <5 h of sleep/day ($P < 0.05$) and those having a medical history of gastrointestinal disease ($P < 0.001$), urinary tract disease ($P < 0.001$), cancer ($P < 0.05$), or previous history of fractures ($P < 0.001$). • Hypertensive participants showed significantly lower PCS scores compared to non-hypertensive ones ($P < 0.001$). • Multivariable analysis results confirmed the descriptive comparisons, besides sleep time, which become non-significant. Unmarried or divorced participants had significantly lower PCS ($P < 0.01$) and MCS scores ($P < 0.001$). • History of chronic diseases such as gastrointestinal disease ($P < 0.001$), cancer ($P < 0.05$), urinary tract disease ($P < 0.001$), and previous history of fractures ($P < 0.001$) were associated with lower MCS scores. Only Hypertension was associated with lower PCS scores ($P < 0.001$). • No lifestyle factors (such as smoking) were associated with lower HRQoL on multivariable analysis.

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Levasseur et al. (24)	The Satisfaction with Life Scale (SWLS)	Personal factors, behavioral determinants, determinants of social environment, determinants of physical environment	• There was no significant difference between the associations of SWLS with accomplishment level and satisfaction with social participation (Olkin's test: $P = 0.71$). In addition, the accomplishment level of social participation was not significant ($P = 0.08$) considering satisfaction with social participation ($P = 0.02$). • Younger age, no higher activity level, recent stressing event, level of activity perceived as stable, better wellbeing, and fewer obstacles in "Physical environment and accessibility" best explained higher social participation accomplishment level ($R^2 = 0.79$; $P < 0.001$) • Apart from environmental factors, little variance (<40%) was explained by each block in satisfaction with social participation compared to the accomplishment level of social participation. Better self-perceived health, level of activity perceived as stable, higher activity level, better wellbeing, and more facilitators in "Social support and attitudes" best explained greater satisfaction with social participation ($R^2 = 0.51$; $P < 0.001$)
Puvill et al. (25)	CASP-12	Personal factors, behavioral determinants, determinants of social environment	• Approximately 0.17% and 0.33% of the variance in life satisfaction was attributed to ADL and IADL disability, respectively (both $p < 0.001$). • The impact of (I)ADL disabilities on life satisfaction was heaviest at age 50, which then decreased gradually with increasing age (p-trend < 0.001). Mental health accounted for more variance for depressive symptoms (5.75%) and loneliness (2.50%), but less variance for social resources (0.09% to 0.47%), all $p < 0.001$.
Ramia and Voicu (7)	WHQOL-BREF	Personal factors, behavioral determinants, determinants of social environment, determinants of health and social services, determinants of the physical environment, economic determinants	• The psychological domain had the least QOL score (mean ± SD: 36.7 ± 20), where more than 28% of older women had "very poor" QOL and 50.6% had moderately poor QOL. Physical- and health-related QOL had the highest mean score (49.5 ± 22), followed by environmental domain (47.38 ± 17) and social domain (43.7 ± 18), where 16.2, 16.2, and 14.4% of older women had "very poor" QOL, respectively. • Risk factors for poor QoL included absence of visits by friends and relatives (COR = 6.1, 95% CI: 1.69–21), age above 70 years (COR = 4.33, 95% CI: 2.21–8.48), neglecting attitude from family members (COR = 4.99, 2.44–10.19), and not having any role in family decisions (COR = 4.2, 95% CI: 1.83–9.56). In addition, low educational level, current and previous unemployment, and low personal and family monthly income were also risk factors, while living in urban areas was a protective factor. • Adjusted models showed age above 70 years (AOR = 11.3), non-possession of property (AOR = 9.0), neglecting attitude of family (AOR = 6.9), and absence of visit by friends and relatives AOR = 9.9) as risk factors, but urban residence, still, as a protective factor (AOR = 0.1) for poor QOL.

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Abdelbasset et al. (26)	EQ-5D- VAS	Personal factors, behavioral determinants, determinants of social environment	• The psychological domain had the least QOL score (mean ± SD:36.7 ± 20), where more than 28% of older women had "very poor" QOL and 50.6% had moderately poor QOL. Physical- and health-related QOL had the highest mean score (49.5 ± 22), followed by environmental domain (47.38 ± 17) and social domain (43.7 ± 18), where 16.2, 16.2, and 14.4% of older women had "very poor" QOL, respectively. • Risk factors for poor QoL included absence of visits by friends and relatives (COR = 6.1, 95% CI: 1.69–21), age above 70 years (COR = 4.33, 95% CI: 2.21–8.48), neglecting attitude from family members (COR = 4.99, 2.44–10.19), and not having any role in family decisions (COR = 4.2, 95% CI: 1.83–9.56). In addition, low educational level, current and previous unemployment, and low personal and family monthly income were also risk factors, while living in urban areas was a protective factor. • Adjusted models showed that age above 70 years (AOR = 11.30, $P < 0.001$), non-possession of property (AOR = 9.0, $P < 0.001$), neglecting attitude by family members (AOR = 6.9, $P < 0.001$), and absence of visit by friends and relatives (AOR = 9.9, $P < 0.001$) were risk factors, while urban residence, still, a significant protective factor (AOR = 0.10, $P < 0.001$).
Dahlberg and McKee (29)	WHO-5 (wellbeing)	Personal factors, behavioral determinants, determinants of social environment, determinants of health and social services, determinants of physical environment, economic determinants	• Neighborhood exclusion accounted for more variance in wellbeing domain in rural compared to urban areas, while exclusion from services accounted for more variance in urban compared to rural areas. • Social exclusion domain: bivariate associations (**beta coefficient**) among social indicators Civic activity 1. Civic non-engagement: −0.09 2. Non-voting behavior: −0.12 3. Low competence for civic participation: −0.21 Material resources 1. Income discomfort: −0.20 2. Non-homeownership: −0.11 3. Low financial resources: −0.13 Social relations 1. Non-cohabitation: −0.08 2. Low contact with friends: −0.18 3. Low social resources: −0.34 Services 1. Poor access to care: −0.24 2. Poor access to amenities: −0.38 3. Poor public transport: −0.18 Neighborhood exclusion 1. Neighborhood alienation: −0.26 2. Neighborhood threat: 0.02 3. Neighborhood indifference: −0.12 There was no significant association between residence area (rural/urban) and age, gender, and years at the current address.

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Neri et al. (28)	CASP-19	Personal factors, behavioral determinants, determinants of social environment	• Perceived QoL was associated with age, mobility, schooling, sociability, instrumental, and emotional support • Participation in social activities (proximal levels); No = 27.6%, Yes = 28.1%, and PR (95% CI): 1.07 (0.87–1.34) Participation in social activities (intermediate level); No = 28.2%, Yes = 27.9%, PR (95% CI): 1.06 (0.94–1.18) • Participation in social activities (distal level); No = 27.0%, Yes = 28.9%, PR (95% CI): 1.11 (1.01–1.22)
Kim et al. (27)	SF 12	Personal factors, behavioral determinants, determinants of social environment	• Lower PCS scores were associated with older age (*OR* = 0.97, 95%CI: 0.94–1.00), having more social support from significant others (*OR* = 0.88, 95% CI: 0.79–0.97), and having an income level of (300,000–390,000 KRW) (*OR* = 0.68, 95%CI: 0.47–0.99). • Good MCS scores were associated with living alone for over 20 years (*OR* = 0.63, 95%CI: 0.45–0.89), performing moderate physical activity (*OR* = 1.61, 95%CI: 1.08–2.38), and receiving social support from significant others (*OR* = 1.20, 95%CI: 1.08–1.34) and friends (*OR* = 1.19, 95%CI: 1.07–1.33). • On controlling for significant demographic variables, social support from significant others had a significant association with a lower PCS score (*OR* = 0.88, 95%CI: 0.79–0.98). However, social support from significant others (*OR* = 1.18, 95%CI: 1.05–1.33) and friends (*OR* = 1.16, 95%CI: 1.03–1.30) has a significant association with higher MCS scores.
Zhang et al. (30)	SF 36; WHQOL-OLD	Personal factors, behavioral determinants, determinants of social environment, determinants of health and social services, determinants of physical environment, economic determinants	• Regarding the physical component of the older participants' HRQOL, exercise, and labor-related factors accounted for the most change in the R^2 value (0.116) • While concerning the mental component, sleep-related (0.054) and leisure-time-activity-related factors (0.053) accounted for the most change in the R^2 value. • Regarding the older adults-specific HRQOL, the leisure-time-activity-related factors caused the biggest change in the R^2 value (0.119), then exercise-and-labor-related factors (0.078).
He et al. (31)	SF-36	Personal factors, behavioral determinants, determinants of social environment	• Participating in social activities was associated with higher scores of health-related QoL. High educational level (OR = 1.59, 95%CI: 1.01–2.29), living alone or with a spouse (*OR* = 1.51, 95%CI: 1.08–2.12), high support utilization (*OR* = 1.13, 95%CI: 1.07–1.21), and high objective social support (*OR* = 1.08, 95%CI: 1.00–1.17) were associated with more social participation among older men. For the older women, high personal income (*OR* = 1.74, 95%CI: 1.25–2.43), single marital status (*OR* = 1.53, 95%CI: 1.11–2.10), overweight (*OR* = 2.28, 95%CI 1.24–4.19), normal weight (*OR* = 1.92, 95%CI: 1.10–3.34), living alone or with a spouse (*OR* = 1.55, 95%CI: 1.20–2.00), subjective (*OR* = 1.15, 95%CI: 1.10–1.20), and objective (*OR* = 1.11, 95%CI: 1.04–1.18) social support and were associated with more social participation.

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Ju et al. (32)	VAS	Personal factors, behavioral determinants, determinants of social environment, economic determinants	• Participants who did not receive a national pension had a QoL of −4.40 (SE = 1.73; $P = 0.0109$), compared to those who had received one. • Moreover, those without a national pension and a low household income had the most significant decrease in QoL (−10.42; SE = 4.53; $P = 0.0214$). • Participants without national pensions and low wealth levels had a considerable decrease in QoL than those with a national pension and low wealth levels (−8.34; SE = 4.14; $P = 0.0438$).
Choi et al. (33)	VAS	Personal factors, behavioral determinants, determinants of social environment	• Individuals with changes from "participation to no participation" (b =2.25, $P < 0.001$), "no participation to participation" (b =3.35, $P < 0.001$), and "consistent participation" (b = 6.62, $P < 0.001$) were more likely to be satisfied with their lives compared to those with "consistent non-participation" (trend: $P < 0.001$). Furthermore, the impact of the positive relationship between consistent participation in social activity and quality of life changed across various aspects of social activity. • Religious activities, leisure/culture clubs, friendship organizations, family/school reunions, and voluntary work particularly had positive associations with consistent participation.
Rugbeer et al. (34)	SF 36	Personal factors, behavioral determinants, determinants of social environment	• A significant difference was found in social function post-training 2 times a week and 3 times a week. • Training three times a week showed an additional benefit in vitality. Improvements in the mental component summary scale post-training two times a week and three times a week were further noted.
Onunkwor et al. (35)	WHOQOL-BREF	Personal factors, behavioral determinants, determinants of social environment, determinants of health and social services, determinants of physical environment, economic determinants	• Gender had significant associations with all domains of QoL (p[[Inline Image]]<[[Inline Image]]0.05), and age was significantly associated with only the physical domain ($p = 0.01$). • The educational level had a significant association with the physical, psychological, and social domains (all p=0.01). Economic status had a significant association with the physical, psychological, and social domains (all p[[Inline Image]]<[[Inline Image]]0.05). • Duration of residence had a significant association with the psychological, social, and environment domains (all p=0.01). • Type of accommodation had a significant association with the psychological, social, and environment domains (all p[[Inline Image]]< 0.05). • Outdoor leisure activity, social support, and chronic co-morbidity had significant associations with all QoL domains ($p \leq 0.05$). • Multivariable models showed that age, gender, economic status, outdoor leisure activity, chronic co-morbidities, and social support had a significant association with the physical QoL domain • The psychological domain had a significant association with gender, educational level, economic status, chronic co-morbidities, outdoor leisure activity, and social support. • The social domain had a significant association with gender, education level, duration of residence, outdoor leisure activity, chronic co-morbidities, and social support. Only chronic co-morbidities and social support had a significant association with the environment domain.

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Haider et al. (36)	WHQOL-BREF	Personal factors, behavioral determinants, determinants of social environment	• Appendicular skeletal muscle mass (ASMM) had no role in the QoL context of prefrail and frail older adults, but balance and Daily Physical Activity had a role, as they had an association with social participation and autonomy. • Model 1: Daily physical activity, handgrip strength, and balance had significant associations with "overall QoL". Balance was significantly associated with the QoL domains of physical health, psychological health, autonomy, environment, and social participation. Gait speed and chair stands were only associated with "social participation" only. • In model 2, independent variables explained overall QoL ($R^2 = 0.32$), physical health ($R^2 = 0.20$), autonomy ($R^2 = 0.247$), and social participation ($R^2 = 0.356$), and in which balance was the strongest determinant.
Marques et al. (37)	CASP-16	Personal factors, behavioral determinants, determinants of social environment	• Overall QoL mean score was 37.6% (95%CI: 37.2–38.1). • Older people with no probable cognitive deficit had higher QoL scores. • Individuals who remained living alone, continued to use the internet, began to work, and began to join groups also had higher QoL scores. QoL mean score of those who remained and became physically active was 41.5 and 40.1%, respectively. • Older adults who continued living with the family reduced QoL by 1.98 points (95% CI: −3.47; −0.50) compared to those who remained alone. However, those who started and remained working had higher QoL, 2.30 (95% CI: 0.45–4.16) and 3.90 (95% CI: 2.36, 5.44), respectively. • Regarding the internet, continued use was associated with a higher QoL score compared to those who stopped using it. All aspects of physical activity have a positive association with QoL scores compared to those who remained less active. • On multivariable analysis, older adults who remained living with their family had reduced QoL scores at 3.33 points (95% CI: −5.06; −1.60) compared to those who lived alone. Older adults who started to work had a positive QoL score ($\beta = 2.82$, 95% CI: 1.42–4.22). • Those who continued using the internet had 2.11 more QoL score points (95% CI: 0.85–3.36) compared to those who never used it. • Older adults who began participating in groups had higher QoL scores by 1.68 points (95% CI: 0.19–3.17) compared to those who did not participate. Regarding physical activity, all aspects remained with significant association. Older adults who remained physically active had higher QoL scores ($\beta = 4.47$, 95% CI: 3.32–5.63) than those who remained less active. Those who were sufficiently active in the first wave, but became less active, still had higher scores than those who remained less active. • Sensitivity analysis revealed associations only among older adults who moved with their family or a caregiver and those who remained working.

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Tavares et al. (38)	WHQOL-BREF, WHQOL-OLD	Determinants of social environment	• The highest QoL mean scores were found in the social relationships domain (71.19) and topic of death and dying (74.30), while the environment domain (60.39) and topic of social participation (63.06) had the lowest scores. • The average score for self-esteem was (9.36 ± 4.09). • Lower self-esteem was associated with significantly lower QoL scores in all the WHOQOL-BREF domains and WHOQOL-OLD aspects (except death and dying) ($p < 0.001$).
Top and Dikmetaş (39)	WHQOL-OLD	Personal factors, behavioral determinants, determinants of social environment	• There was a significant association between QoL and attitudes to the aging of older adults. • The psychological growth subscale of attitudes to aging and sensory abilities subscale of QoL (r = 0.579, P <0.01) had the most significant relationship. Overall, QoL had a significant positive association with overall attitudes to aging (r = 0.408, P <0.01). • Dimensions of attitudes to aging (psychosocial loss, physical change, and psychological growth) were significant determinants of QoL among older adults. • Although gender did not affect overall QOL among older adults, happiness was a significant predictor of overall QOL.
Park et al. (40)	EQ-5D	Personal factors, behavioral determinants, determinants of social environment,	• Average QoL increased with the increasing amount of social activities individuals participated in (zero = 89.30, one = 93.28, two = 95.25, three = 96.27, four = 96.85). When individuals participated in one social activity, social activity had the strongest association with EQ-5D in the older adults age group regardless of gender. Moreover, more participation had a positive association with higher EQ-5D (p for trend < 0.0001). Among women, participating in relationship organizations was associated with a higher EQ-5D compared to participating in other types of social activities

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Bilgili and Arpaci (41)	WHQOL-OLD	Personal factors, behavioral determinants, determinants of social environment, determinants of health and social services, determinants of physical environment, economic determinants	• Older men showed higher average scores for the sub-scales of sensory abilities, social participation, autonomy, past-present-and-future activities, and death-and-dying. However, older women showed higher average scores for the intimacy sub-scales and total average scores. Gender showed significant differences in the mean scores of sub-scales of autonomy, past-present-and-future activities, and intimacy (all $p < 0.01$). • Married older adults showed higher scores in the sub-scales of autonomy, social participation, past-present-and-future activities, and death-and-dying. However, unmarried older adults showed higher scores in the sub-scales of intimacy and sensory abilities. A significant difference in marital status showed significant differences in the mean scores of sub-scales of past-present and future activities, social participation, and death-and-dying ($t = -2.00$; (all $p < 0.05$). Married older adults had significantly higher total scores of QoL than the unmarried, ($p < 0.05$). • Older adults having a child showed higher scores in the sub-scales of sensory abilities and death-and-dying, while those without a child showed higher scores in other sub-scales. Furthermore, older adults with social security showed higher scores in the sub-scales of autonomy, social participation, past-today-and-future activities, and death-and-dying (*all* $p < 0.01$). Older adults having social security showed significantly higher total scores ($p < 0.01$). • Those with diseases showed significantly higher scores in the sensory abilities sub-scale than those without diseases ($p < 0.01$). However, older adults without the disease showed higher scores in the sub-scales of autonomy, social participation, and past-today and future activities (all $p < 0.01$). There was a statistically significant difference in the average total score of QoL according to disease state ($p < 0.01$). • Age (75 years and above) showed significant differences only in sensory abilities, social participation, and intimacy sub-scales (*all* $p < 0.01$). Those of 75 years and above had lower scores in social participation and intimacy sub-scales but higher scores in sensory abilities compared to those aged 60–65 and 66–74 years. • Educational levels of older adults showed significant differences in sensory abilities, autonomy, social participation, past-present and future activities, and death-and-dying (*all* $p < 0.05$) sub-scales (high school with higher scores, except in sensory abilities). • The person whom the older adults lived with showed significant differences in the QOL sub-scales of sensory abilities, past-today and future activities, death-and-dying, social participation, and intimacy (*all* $p < 0.05$). • Income level also showed significant differences in the sub-scales of autonomy, intimacy, past-today and future activities, death-and-dying, and social participation (*all* $p < 0.01$). Additionally, the total average score of the QOL sub-scales of the older adults was associated with their income ($p < 0.01$), with those in much/extreme financial difficulties having lower scores except for intimacy sub-scale scores • Correlation analysis showed a significant positive association of age with sensory abilities, but a negative association between age and social participation and intimacy scores (all $p < 0.01$). Additionally, the total average QoL score was positively associated with education but negatively associated with financial difficulties

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TABLE 4 (Continued)

References	Scale for QOL	QoL determinants	Results
Sampaio et al. (42)	WHQOL-OLD, WHQOL-BREF	Behavioral determinants, determinants of social environment	• Physical activity (β =0.21, P <0.01) had the highest influence on WHOQOL-BREF. This was followed by art activity (β = 0.17, P <0.01) and reading and writing (β =0.14, P <0.01). • Social activity (β =0.22, P <0.01) showed the highest influence on WHOQOL-OLD and then reading and writing activity (β = 0.12, P < 0.05).
Layte et al. (43)	CASP-19	Personal factors, behavioral determinants, determinants of social environment	• The average CASP-19 score was 43.8% (95% CI: 43.6–44.1) and was higher than the average score of the English Longitudinal Study of Aging, 42.5% (95%C1: 42.3–42.7). • Longevity was positively associated with high QoL provided it was accompanied by good levels of mental and physical health, social participation, and high-quality relationships. • Unadjusted analysis showed that CASP-19 was curvilinear with age, peaked at 67 years, and fell after that, while in the adjusted analysis, CASP-19 continued to rise, at a decreasing rate, with increasing age. • Variance in CASP-19 was largely attributed to mental health (7.6%) • Adjusting for variables in the mental health domain showed the lowest slope coefficient for the primary age term, which fell by 50% on adjusting for variables in all of the domains at once. There was a slight reduction in the positive slope coefficient of CASP-19 with age since the quadratic age term was significant and negative in all models
Sewo Sampaio and Ito (44)	WHQOL-OLD, WHQOL-BREF	Personal factors, behavioral determinants, determinants of social environment, determinants of physical environment	• Individuals living in urban areas showed higher total mean QoL scores compared to those in rural areas. • According to WHOQOL-BREF, those living in urban areas showed higher mean scores in the physical, psychological, and environmental domains (*all* P < 0.01) • Participants from urban areas also showed higher participation in reading and writing, contacts with distant friends and family, physical activities, and art activities compared to those from rural areas (*all* P < 0.01). However, those from rural areas were more engaged in work activities compared to their urban counterparts (p < 0.01). • There was a difference in essential activities in the occupational routine between urban and rural participants For the urban participants, the best model included work activity, physical activity, and reading and writing, while for the rural participants, art activity showed a relationship with QOL, other activities were not included.
Guedes et al. (45)	WHOQOL-OLD	Personal factors, determinants of social environment	• More physically active older adults (both genders) showed higher scores in the sensory ability, autonomy, and intimacy domains, as well as significantly higher overall QoL scores (all P < 0.05). • For women, those who were active and very active showed significantly higher scores in the social participation domain compared to sedentary women (p = 0.01), and the variation in scores also varied between genders. • Furthermore, significant differences were noted among men between those who were very active and sedentary, while among women, significant differences were noted between the active and the sedentary.
Gureje et al. (46)	WHQOL-BREF	Personal factors, behavioral determinants, determinants of social environment, economic determinants	• Economic status had a significant association with all four QoL domains. • Considering health variables, functional disability, and self-rated overall health were the most significant, while participation in community activities was the most significant social determinant

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most commonly used questionnaire in various studies was the World Health Organization Quality of Life Assessment–Module for Older Adults (WHOQoL-Old) followed by WHOQOL–Abbreviated Version (WHOQoL-Bref) and the Short Form-36 (SF-36) (5 studies). Similarly, the European Quality of Life-5 Dimension (EQ-5D), Control, Autonomy, Self-Realization, and Pleasure (CASP-19), and visual analog scale (VAS) were used in two studies each. While the Satisfaction with Life Scale (SWLS), SF-12, CASP-12, CASP-16, and WHO-5 were used in one study each.

In examining the relation between active aging determinants and QoL, our study emphasizes that QoL is higher with the better status of active aging determinants, although some contrary findings are observed. It is noticed from many listed studies that social participation and other activities, including reading, art, and physical activities, have a positive impact on QoL (23, 28, 30, 31, 35, 36, 38, 39, 41–46, 48), despite different questionnaires such as WHOQOL-Old, CASP-19, and WHOQoL-Bref were used. Sampaio et al. (42) showed that social activity has the most significant impact on WHOQOL-Old, ensued by reading and writing (42). Similarly, our systematic review also showed that financial security and ensuring care positively influenced the QoL (48). In addition to that, Rugbeer et al. (34) demonstrated that mental and social benefits could be achieved regardless of exercise frequency (34).

The recent study by López-Ortega and Konigsberg (22) considered multiple outcome measures using an SF-36 questionnaire and reported the positive influence of socioeconomic and social, educational, and marital statuses on HRQoL (22), but there was no effect on HRQoL. In addition, there was no effect on HRQoL concerning the number of family members and those having chronic disease conditions. In contrast, another study conducted in the same year in the Shaanxi province of China reported the effect of a chronic condition on physical and mental HRQoL (23). On the contrary, we also acknowledge that not all the possible active aging determinants were associated with QoL among the selected studies. The study by Top and Dikmetaş (39) did not observe a significant association between gender and overall QoL (39). Notably, Onunkwor et al. (35), conducted a study on 203 older adults aged >60 years and failed to associate multiple factors such as pension, ethnicity, marital status, and smoking and alcohol status with any of the domains of QoL (35). Another study by Gureje et al. (46) also did not observe any association between gender, marital status, educational level, and residence and the physical domain of QoL (46). However, one of the studies showed no impact of the recipient of a national pension on QoL among middle-high and high household income levels and wealth (32). Considering most of the studies are based on associations, we support the concept that the higher the score in active aging determinants, the better QoL among older adults. We compared our findings to those of previous studies that investigated the relationship between active aging and QoL (49–52). Our results were consistent with these studies, supporting the notion that higher scores in active aging determinants lead to better QoL among older adults. This finding underlines the importance of promoting active aging to achieve improved QoL outcomes for older adults. Furthermore, a study by Ahmad Bahuri et al. (51) focused on active aging awareness and QoL among pre-elder Malaysian public employees, emphasizing the need to promote active aging in this population to ensure better QoL outcomes (51). Ooi and Ong (52) investigated active aging, psychological wellbeing, and QoL among older adults and pre-older adults Malaysians during movement control periods. Their findings suggest that even in challenging situations like movement control periods, promoting active aging can contribute to improved psychological wellbeing and overall QoL (52).

Our study, therefore, suggests that QoL among older adults is higher among individuals who are advancing well in different active aging components such as health, participation, and security. Our study compiling the previous studies suggests that there is a necessity to manage active aging determinants for the maintenance of QoL properly. Identifying other possible determinants and enhancing the methods to improve those determinants may help improve the QoL among older adults.

Strength and limitations

The main strength of our review is that this is the first study collating information on the association between AA determinants and QoL. Furthermore, stringent search strategy was used in the current study to identify the relevant areas and thus strengthen our interpretation that physical, social, and health determinants are closely associated with QoL. However, as with most of the reviews, our study also has some limitations. Our search was limited to the English language; therefore, any studies published in other languages might have been omitted. Additionally, our literature screening time frame was limited to 2000–2020 as the active aging concept was developed from 2002 onward. Therefore, there might be the possibility of missing any articles that have been published before 2002. Our study's generalizability and interpretation may be affected by factors such as small sample sizes, geographically limited scope, unclear sampling schemes, and imbalanced gender distribution. We recommend future studies prioritize nationally representative studies, detailed sampling schemes, and balanced gender distributions to address these limitations.

Conclusion

The maintenance of QoL in advancing age among older adults is necessary from individual to family, society, and healthcare perspectives. Thus, the elucidation of the related active aging determinants associated with an individual's QoL among older adults is paramount. QoL is multifaceted and is affected by several factors. Previous studies mainly highlighted QoL and clinical condition association; however, the specific aging determinants' association with QoL remains unknown. This review identified and systematically compiled the associated determinants of active aging and QoL. While relatively few studies have been identified, suggesting AA determinants, promising findings pointing to more extensive associations exist. To conclude, the findings from this study could help to further illuminate which AA determinants are essential in the maintenance of QoL. A future study could evaluate the cost necessity to improve the associated active aging determinants of QoL to improve/maintain the overall QoL in a better state.

Author contributions

RM, TS, DM, and PM contributed to conception and design of the study. RM, PK, and SS organized the database. RM, TS, DM, PM, PK, and SS performed the statistical analysis and wrote sections of the manuscript. RM, TS, DM, PM, PK, and SS wrote sections of the manuscript. All authors contributed to manuscript revision, read, 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1193789/full#supplementary-material

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Green space and the health of the older adult during pandemics: a narrative review on the experience of COVID-19

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Introduction: Aging is an inevitable process that leads to changes in various dimensions of older adult life, including physical, psychological, and social aspects. Unfortunately, older adults are more susceptible to health problems caused by adverse experiences such as the Corona outbreak.

Aim: The current study examines the lived experience of older adults in facing the conditions of the Corona epidemic to see how green spaces at various scales can influence the physical and mental health of this group.

Method: Relevant articles published, from 2019 to February 17, 2023, were searched using in the Scopus and Web of Science databases. Eligible studies published in English and all studies passed a quality evaluation.

Result: In the final search, 40 articles were selected and analyzed. The majority of studies conducted during the pandemic categorized the impact of green spaces on the health of older adults into three main categories: Place-based attribute, Process, and Function.

Conclusion: The findings of this study demonstrated that people were using private green spaces (gardens, balconies, etc.), small local green public spaces, sitting and gathering spaces in the neighborhood, nearby open spaces, and urban green-blue spaces throughout the epidemic era. They visited green spaces outside the city and urban areas, including urban gardens, agricultural areas, forestlands, and pastures. In this research, we investigated the characteristics of these spaces and classified them into four physical categories: urban landscape, land use, activity, movement, and accessibility. The results showed that exposure to nature or green space improved physical and mental health and increased attention and decision-making quality in older people. We have proposed design implications recommendations for crises to improve safety, security, and social capital by increasing the safe access of older adults to diverse and high-quality green spaces on different scales, which will ultimately enhance the physical and mental health of people in different age groups.

KEYWORDS

older adults, COVID-19, green space, health, narrative review

1. Introduction

The health issues caused by the COVID-19 pandemic have had severe repercussions for urban areas, including detrimental impacts on urban health, society, and the economy (1). COVID-19 has spread to at least 180 countries around the world and in less than a month, caused 95,000 confirmed cases and almost 3,200 deaths [Chen et al., 2020, as cited in

Adjie and Bahari (2)]. As a result, governments have implemented various lockdown (official order to control the movement of people or vehicles) (3). Policies included, restrictions on attendance at public events and gatherings, restrictions on the use of public transportation, and school closures. Administrations also implemented and created public awareness campaigns about COVID-19 (4). Therefore, many developments have occurred in various socio-economic, cultural, and physical dimensions of the living environment in urban societies, especially for vulnerable groups such as children and older adults.

Access to urban green spaces improves people's quality of life in cities as it allows for the creation of jobs and food, the promotion of biodiversity, urban heat mitigation, and the creation of health advantages (5). Increasing or improving green spaces in public places can have a good impact on all demographic groups, particularly vulnerable groups such as older adults and children (6). While older adults need to live in cities for better social support (7), access to green spaces and usage of health benefits is particularly vital for this population (8). Access to these spaces helps to address public health issues such as obesity, cardiovascular impacts, mental health, and wellbeing (6). Studies have shown that coronavirus has had a stronger impact on most people over 60 years old because the case fatality rate (CFR), which is the ratio of death to infection, is higher in people over 60 years old (4.5%) than in people who are 60 years old or younger (1.4%) (9). The World Health Organization has recommended home lockdown and avoidance of contact with others for this age group, which undoubtedly impacts various aspects of their health, particularly their mental wellbeing (10). In addition, the increase in mental health issues caused by the spread of COVID-19 has led to the disconnection and reduction of social connection for older adults, which exposes them to depression and anxiety and increases their vulnerability (11). Moreover, self-isolation and loneliness can increase the risk of suicide among the older adult population (12). According to Wang and Li (13), the COVID-19 outbreak, as the most prevalent disease, has been the major culprit of moderate-to-severe depression symptoms for 16.5% of urban residents and accounts for 28.8% of moderate-to-severe anxiety symptoms and 8.1% of moderate-to-severe stress symptoms over time.

The COVID-19 crisis has highlighted the vulnerability of the older adult population, particularly in terms of their physical (14) and mental health (15). The pandemic has caused a range of concerns for this demographic including anxiety, depression [(11); Huang and Zhao, 2020; Wang et al., 2020; Zhu et al., 2020, as cited in Dzhambov et al. (16)], uncertainty about the future, limited physical activity, and changes in diet due to fear of going shopping and limited access to health services. As a result, the pandemic's impact on the social, economic (17) environmental, and health aspects of older adults' lives has been significant, and there has been a need to find solutions to mitigate its adverse effects. Urban design has been identified as a potential solution to alleviate the negative impact of the pandemic on older adults. Physical-spatial features of living environments have an impact on the wellbeing of older adults during pandemics and epidemics. Urban green spaces positively affect their health and access to green spaces during lockdown reduces stress, anxiety, and physical health issues (6).

Prior to COVID-19, research consistently shows nature exposure improves mental health and wellbeing. Urban green spaces, water bodies, private gardens, and visual experiences are linked to these benefits. Nature connections also reduce the risk of psychiatric disorders [Bratman et al., 2019; Enge-mann et al., 2019; Tost et al., 2019; De Bell et al., 2020; Jarvis et al., 2021; White et al., 2020; (6) as cited in Nigg et al. (18)]. COVID-19 has emphasized the importance of engagement with green spaces to cope with the stress of the virus' danger and the physical constraints imposed in response (19). A study conducted by Berdejo-Espinola et al. (20), found that people with access to green spaces during lockdown experienced a significant decrease in stress (59%), anxiety (55%), and self-reported physical health symptoms (57%). In addition, other urban design features such as pedestrian qualities, a pleasant environment, and accessible parks have also been found to have a significant impact on health levels of older adults.

According to a study by Zhu and Xu (21), individuals over the age of 60 reported higher levels of life satisfaction during lockdown compared to other age groups. These individuals were able to handle difficult situations more effectively due to their flexibility in daily activities and plans. Older individuals with physical limitations and limited mobility had access to local public spaces for physical activity in their neighborhood. During lockdown, older adults were able to adapt to the situation by using social networks, engaging in mental and physical activities, gardening, changing their daily routines, and adjusting to the circumstances (22). Therefore, when designing and planning residential areas, the specific physical needs of older individuals should be considered.

The COVID-19 pandemic has put the physical and mental health of older adults at risk. However, research has consistently emphasized the importance of green space in improving the health of this vulnerable population (23). However, studies reveal that connected urban green spaces expand people's choices, which increases the spread of the epidemic and makes older adults more vulnerable (24, 25). But numerous studies have shown that the connection of older adults with green spaces on various scales and accessible social distance lowers the physical and psychological symptoms of lockdown, such as desperation, anxiety, mood swings, etc (5, 26, 27). Given the negative social and individual effects of infectious disease on older adults, it is necessary to identify how the physical-spatial factors of their residence can improve the health of older adults in their living environment and neighborhood and identify what role green space plays at different scales. Understanding how measures like lockdown can prevent irreparable consequences and experiences caused by loneliness is crucial.

We try to gain insight into various countries and their experiences. For example, In Ireland, the term "cocooning" emerged, describing the act of staying indoors and isolating oneself from perceived risks rather than going outside. As a result, we employed a qualitative study method to delve deeper into these occurrences and better understand the situation (28). This narrative review study aims to provide a conceptual framework for planning aging in place during the pandemic, focusing on physical-spatial factors. To accomplish this, we reviewed existing literature that discussed the various impacts of the epidemic on this relationship. Based on our findings, we developed a conceptual framework (Figure 1) that aligns with our

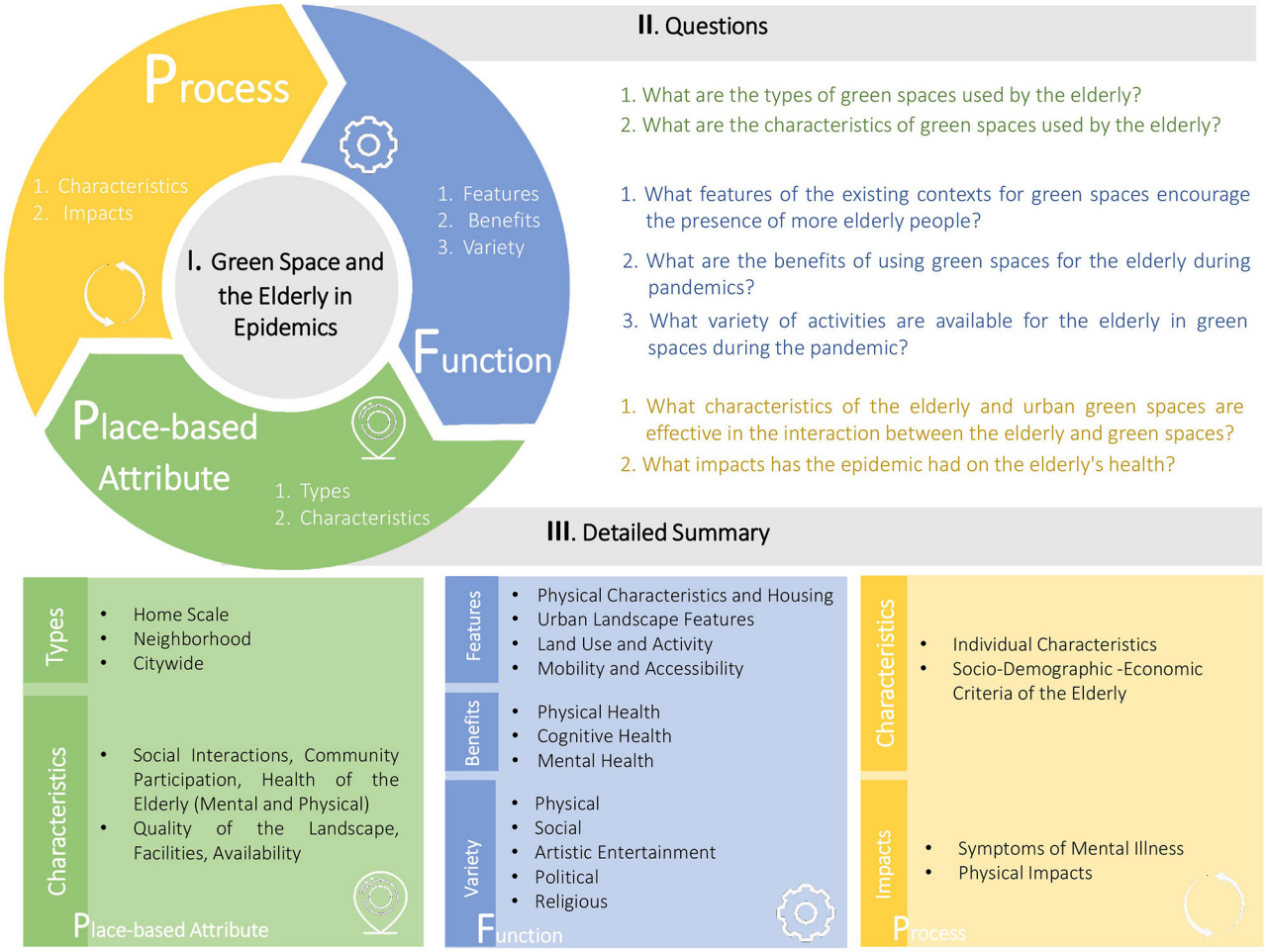

FIGURE 1
Conceptual framework of green space and older adults in epidemics.

research question. The following questions represent the focus of our research:

- 3.1. What impact has the epidemic had on older adults' health?
- 3.2. What are the benefits of using green spaces for older adults during pandemics?
- 3.3. What characteristics of older adults and urban green spaces are effective in the interaction between older adults and green spaces?
- 3.4. What variety of activities are available for older adults in green spaces during the pandemic?
- 3.5. What features of the existing contexts for green spaces encourage the presence of older people?
- 3.6. What are the characteristics of green spaces used by older adults?
- 3.7. What are the types of green spaces used by older adults?

Several articles have explored the utilization of green spaces prior-to and after the COVID-19 pandemic. However, there has been a scarcity of studies focusing on specific population segments, particularly older adults. Although some studies have examined the effect of green spaces on older adults, such as Wu et al. (29), Ali et al. (30), Guida and Carpentieri (31), and Rantanen et al. (32) studies, they have not comprehensively addressed the different aspects of this effect during the epidemic. Therefore, there was a need to examine the specific design implications for green spaces catering to this particular age group.

To gain international insights, the focus was placed on examining various countries, including both developed and undeveloped nations. By considering a diverse range of countries, a more comprehensive understanding of the impact of green spaces on different populations could be achieved. This approach allows for a broader perspective on how green spaces are utilized and their design requirements across different socio-economic contexts.

2. Literature search methodology

While this review is narrative in nature, a systematic search was conducted via Scopus and Web of Science (33) from 2019 to February 17, 2023 in order to ensure that relevant studies were not overlooked (33). The keywords for the search were "urban green space," "coronavirus," and "older adult people."

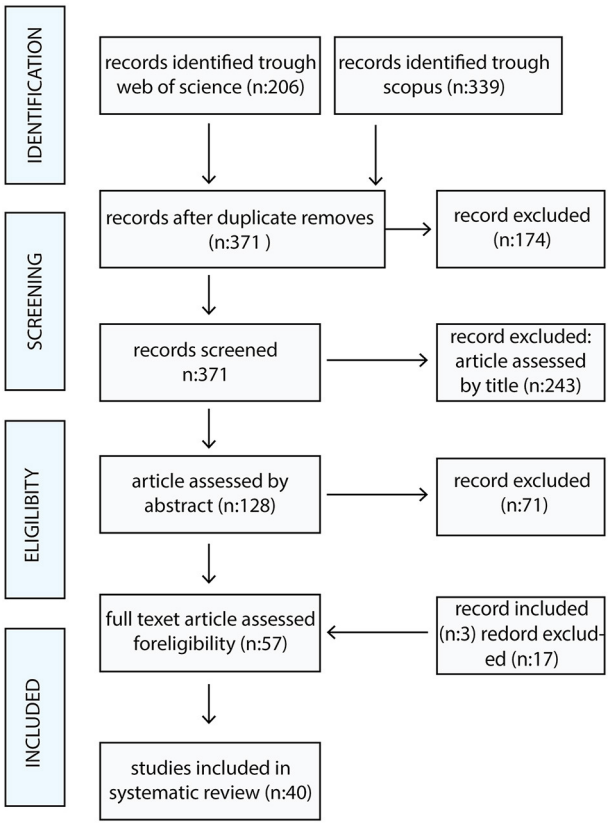

FIGURE 2
Flowchart of article selection.

In the initial search, 339 and 206 articles were identified; after removing duplicates and studies with only an abstract, 371 articles remained. Finally, two inclusion criteria were used to select articles: (a) articles should be written in English; (b) they should be on the relationship between the features of the built environment and the physical health of older adults. A total of 40 articles were ultimately chosen and evaluated after examining the titles and abstracts of 128 articles (Figure 2). Finally, a conceptual framework with three categories was developed: Place-based attribute, Process, and Function.

3. Results

3.1. What impact has the epidemic had on older adults' health?

The unequal distribution of COVID-19 and the uncertainty associated with this disease have harmed the health of older adults on both an individual and communal level (34). Oliveira et al. (35) have found that the degree of physical activity and lifestyle during the pandemic have had a significant impact on older adults. A considerable fall in physical activity levels throughout the lockdown has negatively influenced the level of physical fitness and increased sedentary lifestyles factors that have been directly associated with increasing weakness in this group.

Studies show that the mental health status of older adults has been negatively impacted during the pandemic. Some preventive measures that have been taken to increase the resilience of older adults seem to change their living conditions during lockdown and help them deal with self-isolation, social distancing, and stress disorders. However, in their study, Perlman and Peplau (36) showed an increase in aging symptoms in people due to a decrease in immunity and a rise in anxiety during this period. Loneliness or the lack of social relationships was among the issues that older adults experienced more than other people due to being in a high-risk group.

This group was also affected by the adherence to lockdown rules and the lack of communication with the outside world, the emotional loneliness brought on by the absence of an intimate relationship or an emotional dependency [Weiss, 1974, as cited in Gaaloul et al. (37)], and the social loneliness caused by the absence of communication with a larger group of contacts. Van Tilburg et al. (38) asserted that many older individuals adopted social media as a substitute for in-person communication during the epidemic because of the decline in social connections. According to Pouso et al. (26), there was no significant difference in the level of depression between people with partial restrictions and people without restrictions to access public open spaces and green spaces. This result showed the importance of contact with nature to maintain mental health and emphasized the quality of being in green space rather than its quantity. Despite the time limit imposed by authorities, the use of green spaces has a great impact on mental health (26) and the physical health of older adults (39).

The sense of isolation among older adults can also be attributed to individual factors. Research has shown that age greatly impacts access to services and amenities, as well as participation in cultural and leisure activities. Additionally, factors such as retirement and marital status may contribute to feelings of loneliness and isolation (40). Despite the effect of physical distancing policies on social isolation, such effects are only seen in married people or those who are not in touch with others through social networks (38).

In the various reviews, some policies need to be established to create friendly communities for older adults. In this context, places far from the community should be examined, people far from social activities should be studied, and policies at the neighborhood scale to increase social participation should be considered [(38); Table 1] shows the effects of Corona on the health of older adults.

3.2. What are the benefits of using green spaces for older adults during pandemics?

Numerous studies have demonstrated that exposure to natural environments offers extensive physical and psychological benefits (18). These effects have been observed in various study designs, including experimental, ecological, cross-sectional, and longitudinal studies. It is important to note that the definition of "natural environment" varies among these studies and encompasses green spaces, parks, nature, outdoor environments, and more. Specifically, exposure to green spaces serves three key functions: reducing harm (e.g., minimizing air, noise, and heat pollution), restoring capabilities (e.g., physiological restoration and

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TABLE 1 The effects of coronaviruses on the health of older adults (mental and physical; source: Authors).

Characteristics		The number of repetitions	References
Symptoms of mental illness	Anxiety	11	(9, 10, 15, 16, 24, 26, 27, 38, 41–43)
	Depression and frustration	9	(9, 10, 15, 16, 24, 26, 27, 38, 41)
	Fear	6	(16, 24, 27, 38, 44)
	Social relationships of the individual	5	(32, 44–47)
	The prevalence of the disease	1	(48)
	Lack of desire and pleasure in doing things	1	(24)
	Increasing of spending time at home	2	(16, 46)
	Bad temper	1	(27)
	Sorrow	1	(38)
	Weak concentration	1	(27)
	Changes in diet	1	(16)
	Suicide (especially in nursing homes)	1	(9)
	Homesick	1	(38)
	Decreased cognitive ability in old age	1	(41)
	Decreased mental activity	1	(44)
	Absurdity	1	(38)
	The feeling of crime	1	(24)
	Personality characteristics	1	(41)
	Returning to mental habits (alcohol, drugs, cigarettes...)	2	(9, 43)
	Inability to control worry	2	(24, 27)
	Quality in sleep	3	(10, 16, 27)
	Tiredness	2	(16, 27)
	The amount of physical activity inside and outside the home	5	(39, 44, 47, 49, 50)
	Increase in body mass index	1	(10)
	Height and weight	1	(51)
	Reduce physical activity	3	(38, 42, 51)
	Reducing the percentage of positive tests	2	(15, 52)
	Deterioration of diet	1	(44)
	Increasing the amount of disability	1	(53)

improvement), and fostering capabilities (e.g., promoting physical activity and facilitating social cohesion). Despite the diversity in study designs and definitions of exposure, we have compiled relevant evidence to establish the positive impact of outdoor environments (natural or built environment) on various health domains, as summarized in Table 2.

During lockdown, it is possible to enhance the mental and behavioral health of older adults by considering their personality traits, such as higher intelligence, emotional stability, and extroversion, while also promoting public communication [Killingsworth and Gilbert, 2010; Tost et al., 2019 as cited in Nigg et al. (18)]. Access to outdoor recreational facilities and nearby parks, as well as increased physical activities, can contribute to maintaining physical and mental wellbeing and establishing safe social relations during the pandemic, as environmental-spatial characteristics play a role in these aspects (1). Urban parks don't only benefit mental and physical health but also facilitate the development of social relations within neighborhoods [Hayward and Weitzer, 1984; Lloyd et al., 2008 as cited in Addas et al. (54)]. Considering the special physical needs of older individuals, it is crucial to ensure their presence and provide thoughtful design and planning of outdoor environments in residential areas during pandemics.

In a study by Bartalucci et al. (55), the comparison of the data before and during the lockdown period showed some improvements in people's perception of nature and the sounds of the environment. During the lockdown, people paid more attention to the sounds around them. Such improvement in the sound landscape was associated with the reduction of road, air, and rail traffic (55). The study also found that older people over the age of

TABLE 2 The positive impact of external environments (natural/constructed environment) on different areas of health [source: Levinger et al. (1)].

Physical health	Cognitive health	Mental health
• Increase physical activity • Increase walking • Increase participation in casual/recreational activities • Increasing adherence to recommended guidelines in physical activity • Improving physical disorders and functional limitations • Reducing mortality from various diseases • Physiological benefits (e.g., increased immune system function)	• Improve focus and attention • Overcoming mental fatigue • Improving global decision-making processes	• Improves mood • Reducing stress • Increasing social connections

60 were more sensitive to traffic noise during the lockdown period, which was likely associated with understanding sounds and their natural environment. Furthermore, with the reduction of traffic noise, the quality of the soundscape improved (56). The study claims that if a person lives alone, their judgment of various aspects of their surroundings will be more positive. However, the lockdown itself can hurt human perception. Changes in people's behavior due to an epidemic like COVID-19 can have positive effects on the environment, particularly regarding the soundscape (55).

The emphasis on green space in previous reviews has been consistent. However, other forms of nature, such as blue space [e.g., rivers or lakes; Britton et al., 2020 as cited in Nigg et al. (18)], green infrastructure, which pertains to a deliberate network of open spaces, and digital nature experiences (18) have unfortunately been overlooked.

3.3. What characteristics of older adults and urban green spaces are effective in the interaction between older adults and green spaces?

In 40 selected articles, the focus was on factors such as the density of commercial facilities, the density of schools, access to public transportation, the density of roads, and access to green spaces, along with the environmental characteristics of built space, such as urban density and mixed language use, the health impacts of urban residents' land use, and long-term active travel behaviors.

Older adults, as a vulnerable group of people to epidemic diseases, rarely use green space due to the dread of infection (57). They are subject to the negative impacts of social isolation, dread of disease, despair (17), and depression (58). Providing green spaces in the vicinity of areas where a large number of older people live can satisfy their need for greenery, prevent social isolation, despair, and increase social interactions (20). As physical activity is closely linked to mental health, older adults' limited physical activity and lack of access to physical activities either online or at home during lockdown have damaged their health (41). Inactivity intensified by social isolation measures to combat COVID-19 can make the health conditions of older adults worse than others, resulting in sarcopenia, weakness, and cardiac abnormalities, which all can potentially lead to increased mortality issues. These problems can put them at risk of death. Efforts to develop measures related to public health and clinical interventions in physical activities are necessary during COVID-19 (49). In one research they concluded that older users of green spaces tended to spend more time in their yards than those who did not visit green spaces much [Lin et al., 2014, cited in Berdejo-Espinola et al. (20)]. This is against the assumption that those who have access to green spaces are not in the need of greenery.

This narrative review study shows that some socio-demographic factors (such as age, gender, and education) (54), and activity status of older adults, along with their racial characteristics, affect the use of urban space by older adults. A variety of factors, such as the socio-economic characteristics (59) of the place of residence, the sense of isolation and loneliness (53) and the attachment to the place, have also affected the quality of their presence in the urban space. Table 3 shows a summary of the conducted studies. Visitors' behavior in green spaces correlated with their status and occupation. Local residents who owned their own houses, had long years of housing, stable jobs, and higher education outperformed others in behavior and health perceptions when visiting green spaces (65).

3.4. What variety of activities are available for older adults in green spaces during the pandemic?

During the COVID-19 pandemic, the requirements to observe social distancing highlight to what extent the quality of life (QOL) is related to social and physical activity in middle and old age. They also show the necessity for more mobility in the living space. During lockdown, the amount of activity and mobility of middle-aged people at home or in private outdoor spaces decreased (32). A study conducted among 60-year-old people in the early stages of social distancing in Sweden in 2020 showed that the level of satisfaction with the quality of life and feeling of loneliness did not change much, but the level of health and satisfaction with economic conditions changed, and as time went on, a greater impact on the physical and mental conditions of older adults was observed. This is because social distancing policies have either reduced or eliminated opportunities for outdoor activities such as events, artistic entertainment, social gatherings, sports classes, and political and religious meetings (32).

Urban green spaces are mainly used for various activities, such as running, walking, and outdoor sports, which depend on many interconnected variables and the type of city texture, including the construction and population density of the neighborhood, the amount of green space available, and the safety and security of traffic and crime (66). With regards to older people, men tend to exercise alone while women tend to exercise in groups. However,

TABLE 3 Individual and socio- demographic characteristics of residence of older adults (source: Authors).

Characteristics			The number of repetitions	References
Individual characteristics	Age		20	(10, 15, 16, 20, 21, 24, 26, 27, 31, 44, 46, 50–53, 55, 60–63)
	Gender		17	(10, 15, 16, 20, 21, 24, 26, 27, 41, 44, 50–52, 55, 60, 61, 63)
	Education level		13	[(10, 15, 24, 26, 27, 38, 41, 44, 50, 53, 55, 62, 64)
	Ethnicity		7	(16, 46, 52, 53, 61, 62)
Socio-demographic -economic criteria of the older adult	Socio-economic situation of the neighborhood	Social support	2	(16, 64)
		Poverty	3	(52, 53, 61)
		Marital status	3	(26, 38, 62)
		Language	3	(25, 38, 53)
		Number of men and women	1	(52)
		Children	2	(26, 61)
		Number and capacity of nursing homes	1	(53)
		Family size	5	(15, 16, 26, 61, 62)
		People in need of care	2	(26, 53)
		Health insurance status	3	(52, 53, 62)
		Income	11	(10, 16, 20, 24, 26, 27, 38, 44, 46, 50, 52)
		Employment-unemployment	11	(10, 24, 26, 27, 38, 41, 52, 53, 55, 62, 64)
	Loneliness	The presence of pets in the house	2	(26, 27)
		Duration of visiting the green space	1	(24)
		Social isolation	4	(9, 38, 42, 44)
		Social security	1	(48)
		Living alone	5	(10, 27, 41, 53, 63)
	Sense of belonging	People's participation in neighborhood activities	3	(5, 46, 64)
		Duration of living in the place	1	(46)
		Sense of belonging to the neighborhood	2	(16, 64)

due to the spread of COVID-19, the absence of group activities and gyms may have led to a reduction in the time women spend walking (60). There is no doubt that the presence of large parks within residential areas has increased the amount of walking, especially for older adults, and the relationship between the distance to the park and the change in the amount of daily walking in older women is very evident (60). According to a survey, 40% of park-users are aged 60 years or older, and among this age group, 90% visit the park on a daily basis. In summary, the survey indicates that ~86% of older individuals visit a green space located within a 1-kilometer distance from their residence (30).

The study by Noszczyk et al. (67), in which 1,250 people participated, shows that people mentioned different reasons for visiting green spaces: walking outdoors (69.8%), improving general health (68.9%), access (65.7%), and the need to connect with nature (60.6%). It is interesting to note that playing sports at gyms and walking with pets were not the main reasons for residents to visit green spaces (67). More than 75% of the participants claimed that visiting green spaces had a very (42.2%) or great (34.5%) effect on reducing their stress, and only 4.3% believed that visiting green spaces was not effective in reducing their anxiety. More than 60% of the respondents expressed the need for physical activity, the possibility of spending time with family and friends, and reducing the feeling of depression as the reasons for visiting green spaces during the COVID-19 pandemic (67). In another study, the most important reason for people to visit green spaces was to improve their mental health (77.4%), followed by increasing their health and physical activity (62.8%) and the possibility of connecting with nature (52.4%). Being in green spaces to use clean air was the main reason for 32.0% of the people, while the need for gathering and social connection was only important for 6.4% of the participants (20). Visiting green spaces is primarily motivated by individual health concerns, as demonstrated by a survey conducted in another country. For example, in a survey conducted by the

Department of Planning, Industry, and Environment in Australia, personal sports activities such as walking, running, fitness sports, and cycling were found to be the main reasons for using public spaces [NSW Department of Planning, Industry and Environment, 2020, as cited in Levinger et al. (1)]. Furthermore, older adults reported walking on the streets near their residences. From this, scholars emphasize the importance of "no traffic" streets for people to continue exercising with social distance (68).

3.5. What features of the existing contexts for green spaces encourage the presence of more older adult people?

Several studies have indicated that the physical and spatial characteristics of a neighborhood can influence the attendance of older adult individuals during the COVID-19 pandemic. Factors such as the physical attributes of housing, urban landscapes, land use, and activity levels have been found to impact the quality of attendance for this population (Figure 3). Notably, the building and population density of the neighborhood, as well as the quality of corridors providing views to green spaces inside and around the neighborhood, have shown the greatest impact (Table 4). The availability of transportation options, such as vehicles, public transportation, bicycles, and access to technology in the neighborhood, including routing and augmented reality (AR) technology, elevators, sound-sensitive doors, and smart homes, have also encouraged greater attendance among older individuals. Furthermore, increased visits to urban green spaces were closely related to the distribution of green spaces around parks and neighborhoods (65, 71).

The characteristics of the local environment in the neighborhood level play a vital role in promoting adaptive behaviors and enhancing the health and wellbeing of older adults. For instance, a study conducted in New York demonstrated that individuals living in disadvantaged neighborhoods, who faced challenges in leaving their homes due to physical disabilities, encountered similar difficulties (1). Those with functional limitations or a perception of an unsafe neighborhood had significantly lower mental health compared to those who considered their area of residence safe. This disparity in mental health could be attributed to reduced social cohesion in these neighborhoods, which exacerbates the negative effects of a lack of safety [Cramm et al., 2013; Carrapatoso et al., 2018; Choi and Matz-Costa, 2018; Bonaccorsi et al., 2020, as cited in Levinger et al. (1)].

However, the presence of greenspace alone does not guarantee access. Barriers such as inadequate transportation, connectivity infrastructure, provisions for disability, and socio-cultural issues, including harassment and violence against women, continue to persist (72). In summary, the benefits of green infrastructure depend on individuals' previous experiences with greenspace, perceived accessibility, and personal connections to the landscape [Wang et al., 2015; Roberts et al., 2019; Grilli et al., 2020; Groshong et al., 2020; Sonti et al., 2020, as cited in Maurer et al. (72)]. Additionally, socio-demographic attributes have a substantial impact on the use, attitudes, and perception of urban parks (54).

3.6. What are the characteristics of green spaces used by older adults?

Neglecting the quality of design in green spaces, both in terms of their qualitative and quantitative aspects, can have detrimental effects on social interactions, civic participation, community involvement, and the health of older adults [Hassen and Kaufman, 2016, as cited in Levinger et al. (1)]. Due to concerns about disease transmission, people have been avoiding public transportation, leading many cities, such as New York, to allocate open spaces and streets primarily for pedestrians and cyclists (61).

While engaging in outdoor physical activities and being exposed directly to nature have been found to have a more positive impact on health, indirect contact with green spaces, such as viewing them from a window, has been evaluated positively for maintaining the mental health of individuals during strict lockdown conditions, as observed in Spain (26).

Although the restrictions imposed during the COVID-19 pandemic may not have altered the need for urban green spaces, they have increased people's desire to visit a variety of green spaces. For instance, some individuals have traveled outside the city, while others have stayed within urban areas. Tree-lined streets and urban green spaces have been particularly sought after. As a result, the desire for trips with environmental effects has grown when access to pocket parks is not available (45). The older adult population not only requires green spaces but also tends to travel longer distances within or outside the city to access urban green areas. The green spaces utilized by older adults should be located in densely populated environments and possess important features in terms of land use (45). The availability of green pathways within the street network is one of the factors influencing older adults when selecting a location for physical activity. Other factors, including the quality of the landscape, amenities, the surrounding environment, and space availability, also play a role in people's choices. In order to enhance access to appropriate infrastructure for walking, cycling, and engaging in key activities while maintaining social distancing, the need for a variety of transportation options increases, as it not only enables older adults to participate but also contributes to societal cohesion and flexibility through increased social interactions (73).

3.7. What are the types of green spaces used by older adults?

The difference in the use of green spaces by older adults is associated with their physical limitations, socio-economic characteristics, and living conditions. The green space used by older adults has been studied at different scales, ranging from home green spaces, neighborhood yards, and gardens, to large urban areas (21). In a study conducted in England and Scotland in 2020, it was found that older people spent less time in green spaces during lockdown (24). The fear of infection and death caused this age group to comply with the lockdown conditions, which led to many problems for the health of this group of people. Many studies have claimed that the amount and frequency of use of green spaces by older adults

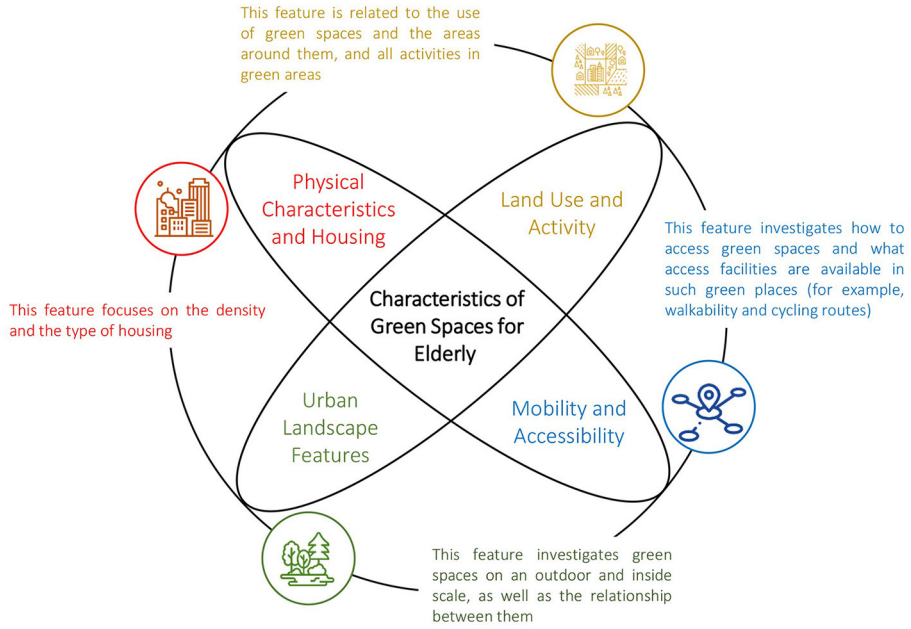

FIGURE 3
Characteristics of green spaces for older adult.

is related to their health [(1, 16, 20, 22); Guida and Carpentieri, 2021]. Appendix Table 1 briefly presents the types of green spaces used by older adults during the pandemic.

Pouso et al. (26) investigated the effect of interacting with nature on depression levels using indirect access (containing the presence of both an urban and natural scene or a combination of both) and direct access (including the presence of a garden and green space and access to a terrace balcony).

Posuso et al. identified three levels of lockdown: level 1, which permits people to go out only for essential jobs, buying food and medicine, emergencies, or walking the dog (as implemented in China, Italy, or Spain); level 2, which enforces strict lockdown but allows for outdoor exercise on certain days (as implemented in France or England); and level 3, which also enforces strict lockdown but permits outdoor exercise on certain days (as implemented in France or England) (26). Also, the restriction of movement is a recommendation rather than a binding rule. This is most likely due to the high feeling of comfort from the absence of infection and the possibility of the naturalness of the space compared to balconies, compared to being in public or shared green spaces (26).

According to Pouso et al. (26), contact with nature through houseplants and balcony gardens can reduce the probability of depression and anxiety symptoms only for people in severe lockdown. As other groups leave the house more often, access to nature becomes easier for them, and in this way, stress can be reduced. The existence of private gardens and gardening spaces in patios can contribute the most to improving mental health during the pandemic as it provides access to open space and increases physical activity (26).

The diversity and abundance of plants and greenery that can be seen from windows, terraces, balconies, or in the neighborhood, as well as the addition of having houseplants or a garden, and greenery, have also been related to mental health. The existence of common green spaces also has been reported to create communication between neighbors, increase support and participation between people, and reduce the feeling of isolation among older adults (16). In the United Kingdom, a study was conducted to investigate the relationship between the size of the garden and the health of older adults, and it showed that people with larger gardens that they tended to themselves had better general health [Brindley et al., 2018, as cited in Dzhambov et al. (16)] and improved dietary intake [Davis et al., 2011; Beavers et al., 2020, as cited in Nigg et al. (18)], it may be sustained effects on healthy eating behaviors (18). Studies found that more older adults visited regional parks with large areas after COVID-19. But for small-scale parks including community parks, neighborhood parks, and paly lots, older adult visitation was negatively affected by COVID-19 (74).

In an online survey conducted in Italy, Spano et al. investigated the relationship between the presence of green spaces inside and outside the home (i.e., the presence of pots, sunlight, green landscapes, and access to private green spaces and the natural environment outside) with the level of depression, anger, anxiety, and insomnia. They found that the presence of flower pots in the house and green spaces outside the house reduced mental health problems in people during lockdown (27). During the pandemic, the green walls of buildings (especially during lockdown) played a small role in creating a sense of connection with nature and somehow increased the sense of freedom of older adults (45). In another survey conducted among 2,969 individuals in Scotland to investigate the level of psychological problems during the COVID-19 pandemic, researchers concluded that residents of urban areas, people living in deprived areas, those who do not have access to green spaces in their residential areas, and individuals who do not

TABLE 4 Characteristics of green spaces (source: Authors).

Characteristics		The number of repetitions	References
Physical characteristics and housing	Density	7	(42, 50, 52, 55, 60, 61, 69)
	Housing type	1	(16)
	Topography	1	(31)
Urban landscape features	The palette of the environment	1	(15)
	Indoor greenery	3	(10, 16, 27)
	Sky landscape	1	(15)
	Artworks at home	1	(15)
	The quality of receiving light in the house and neighborhood	1	(27)
	Soundscape	2	(47, 55)
	The amount of urban green space	2	(20, 64)
	Lighting and lightening	2	(42, 47)
	Tree-lined streets	1	(45)
	Proportion of urban or rural residence	1	(24)
	A view of greenery from inside the house (outside view)	4	(15, 16, 26, 27)
Land use and activity	Diversity and density of uses around the green space	2	(50, 70)
	The number of green spots around the neighborhood	1	(48)
	Number of parks	1	(61)
	Brownfield	1	(48)
	Possibility of presence with pets	2	(45, 47)
	The possibility of taking children out	1	(45)
	Access to technology in the neighborhood	6	(22, 32, 44, 53, 62, 64)
	Connecting neighborhoods and green spaces with designed routes	1	(52)
	Access to home garden and fresh fruits and vegetables	1	(47)
	Access to urban agricultural lands	1	(66)
	Access to green-blue infrastructure		(47, 70)
Mobility and accessibility	Access to public transportation	2	(31, 42, 47, 60, 64)
	The distance to the neighborhood market	5	(69)
	Mode/type of travel (having a vehicle, public transportation, bicycle, etc.) to the green space	1	(42, 45, 47, 53, 61, 62, 70)
	Security of intersections	6	(70)
	Congestion and reduction of traffic	1	(42, 69, 70)
	Street design and pattern	3	(50, 70)
	Percentage of sidewalks	2	(42, 61)
	Bicycle route	2	(70)
	Walkability	1	(44, 47, 70)

use green spaces outside of their homes have had more problems compared to those who live in rural areas (24).

In another study in Scotland, the effect of the following three variables was investigated: gardening in the garden, relaxing in the garden, using the garden before and after the COVID pandemic. According to the findings, older people in Scotland spent more time in the garden during the COVID-19 lockdown, and compared to before the lockdown, they reported better physical health, emotional health, mental health, and sleep quality (10).

During the COVID pandemic, the existence of small-scale green spaces has been very effective for mental activity as well as strengthening physical health, especially for older adults (10). Based on these regulations and guidelines regarding the presence of a home garden, such a space will be important for maintaining physical activity for older adults at home. Among the issues examined in long-term planning for design and construction laws are changing in the design and use of common residential spaces for residents. There are some short-term plans, such as allowing

private use of open and green spaces on certain days for each family, which also had a positive impact (24). The report has shown that in the absence of a balcony or a backyard, the use of green spaces in the yard and the green spaces, especially the private garden available in the vicinity of the residence, has increased. Therefore, it is necessary to provide sufficient green space in the neighborhoods and the vicinity of the residential space (75). During the pandemic, the design of public space to provide sufficient green physical space in compliance with policies against the spread of infectious diseases has become particularly important to the effectiveness of these programs and green spaces (61).

4. Discussion

In our study, we have developed a conceptual framework (Figure 1) based on our research findings. To organize and categorize our findings effectively, we have classified them into three distinct categories: place-based attributes, processes, and functions. This classification allows us to better understand and analyze the various aspects related to our research topic. By considering these categories, we aim to provide a comprehensive and structured understanding of the subject matter at hand.

4.1. The importance of urban green spaces for older adults during the pandemic

There is a positive relationship between physical activity and the proximity, accessibility, size, quantity, and quality of urban green spaces [Coombes et al., 2010; Zhang et al., 2017; Klompmaker et al., 2018, as cited in Zwierzchowska et al. (76)]. The World Health Organization (WHO) recommends that adults engage in at least 150 min of physical activities per week to maintain physical and mental health, and during epidemics when those activities for older people are limited, home and outdoor exercises need to be replaced (35). However, unfortunately, during the COVID-19 pandemic, lockdown led to a decrease in physical activity levels among the older adult population worldwide, with important factors including an increase in sitting time and sedentary behavior, a decrease in metabolism, and a reduction in the number of walks taken and even using the green spaces.

To highlight the benefits of green spaces in older adults' lives in this narrative review, worth noting is that, during the pandemic, living in greener neighborhoods with more public green spaces can increase older people's willingness to engage in physical activities such as walking and cycling (29) as well as relaxation (65). Furthermore, individuals residing in greener areas have reported experiencing milder pandemic fatigue (29) and a lesser decline in physical activity and leisure time (50). Interestingly, there has been a significant increase in the number of individuals spending more than 2 h in these spaces after the pandemic, suggesting a preference for outdoor activities among residents. Additionally, there has been an observed rise in visits with multiple companions (65). Although increasing urban agriculture in city centers is challenging, urban farms can improve mental wellbeing by enabling residents to grow food within 100–250 m of their homes, particularly during pandemics (77). Seasonal and age-related factors have influenced the reported behavioral changes in visiting parks among older people during COVID-19. However, promoting older adults' wellbeing needs to incorporate available green networks, such as pocket parks and roof gardens, into residential neighborhoods (50). Nature-based solutions, including green infrastructure (GI), nature restoration, and forest landscape restoration, focusing on urban greening (UG), are also crucial for maintaining cities' health and wellbeing during crises. These nature-based infrastructure areas are vital for conservation and enhancement (66).

Having more benefits of green space during the pandemic depends on reducing transmission by design based on three crucial factors: the density of development and construction, the level of connectivity and design of green infrastructure, and the availability of urban green-blue spaces (48). To minimize the risk of disease transmission, it is necessary to create distance between green spaces to discourage individuals from choosing these spaces as alternative options. The selection of green spaces determines the potential for movement within the urban space network, reflecting people's inclination to use green spaces as destinations or pathways. Planners can reduce the degree of selection by designing green spaces in pedestrian-friendly areas rather than focusing solely on primary nodes and traffic links (25). Therefore, flexible policies are required to ensure access to green spaces at various scales, and monitoring exercise, either through regular visits or phone calls, can be effective in enhancing the benefits of exercising at home [Chen et al., 2021, as cited in Oliveira et al. (35)].

Furthermore, Poh et al. (78) have found that the risk of infection is lower in urban areas with forests and green spaces, while it is higher in areas with denser urbanization patterns, often indicating higher population accumulation. According to Zhang et al. (62), population density is the most significant factor in determining the risk of contamination, followed by traffic density. On the other hand, the distance from markets and commercial spaces has a lesser impact on the spread of the disease. Finally, Ye and Qiu (48) discovered that factors such as forest patches, forest edge density, and the proportion of green edges are associated with infectious disease risk, as green infrastructure, including tall trees, is critical in preventing disease transmission.

4.2. Effective characteristics to design green spaces for older adults during pandemics

4.2.1. Socio-demographic and economic characteristics influencing the design of green spaces in pandemics

Researchers have extensively confirmed the impact of "place-oriented" factors on health outcomes [Janssen et al., 2006, as cited in Oluyomi et al. (53)]. The places where individuals reside, work, and socialize have all significantly enhanced the quality of life for older adults during the pandemic (53). This effect appears to have been amplified by various neighborhood characteristics, such as social condition, ethnicity, income, and the health status of older adults [Haan et al., 1987, as cited in Oluyomi et al. (53)], which influenced some factors such as access to care, hygiene, healthy food, recreational activities, the built environment, and

neighborhood safety. Psychological resilience, age, and gender of older people have also proven to be important factors affecting the likelihood of experiencing depression and anxiety symptoms during COVID-19. Younger individuals are more susceptible to depression than older individuals, and women have experienced higher levels of psychological pressure than men (26).

Numerous social and economic factors, including age, gender, education, income, race, female-to-male population ratio, employment status, and occupation type, can influence the risk of COVID-19 (52). Individual traits such as poor health, low media literacy, advanced age, tall stature, and male gender (40) can also contribute to this risk.

Furthermore, there is a significant relationship between education level, engagement in sports, and recreational activities in urban green spaces during the epidemic. Individuals with higher education tend to recognize the importance of utilizing green spaces and improving their mental wellbeing while staying at home (77). Occupation has also been linked to exercise frequency, engagement in recreational activities, and the use of recreational spaces. For instance, individuals working in public or private jobs have the highest number of visits to green spaces (25.42%), followed by those not employed (24.82%). Monthly income is also associated with the willingness to exercise, frequency of recreational activities, and inclination to travel outside the city to access green spaces (79).

Notably, Van Tilburg et al. (38) found that elevated mental health issues, particularly emotional loneliness, are associated with individual harm, pandemic-related concerns, and decreased trust in social institutions. To promote wellbeing through addressing social distancing-related challenges among independently living older adults, the most effective interventions involve facilitating social connections, including contact with social institutions, to alleviate feelings of fear and isolation (38). A study focusing on individuals over 84 found that participants experienced an increased need for social support during this period. This positive change can be attributed to more excellent online or phone contact with family and friends, leading to a healthier life for these individuals (41).

Besides, some research indicates that older individuals in disadvantaged neighborhoods face higher social exclusion levels than in other neighborhoods. This discrepancy arises from neighborhood deprivation in areas such as access to services and amenities, social relations and civic participation, and cultural and recreational activities, as well as green spaces (40). The COVID-19 pandemic has exacerbated existing inequalities rooted in neighborhoods, with individuals of all ages in the most deprived areas of England and Wales being twice as likely to experience COVID-19 compared to those in more affluent neighborhoods [Office for National Statistics, 2022, as cited in Shoari et al. (34)]. Also, vulnerable populations, including older adults and individuals with low socio-economic status, face increased risks, as those in low-income neighborhoods also tend to have limited access to green spaces. Labib et al. (66) indicate that populations exposed to greener environments experience lower health inequities.

Moreover, the rate of COVID-19 infections is directly related to the percentage of the black population, non-native immigrants, households without access to a vehicle, and the population over 65 years old (53). The pandemic has disproportionately affected certain groups based on age, race, ethnicity, gender, disability, and sexual orientation. The spread of COVID-19 has also led to increased social stigma and discriminatory behaviors against specific ethnic backgrounds, individuals with disabilities, and marginalized groups (46). A qualitative study conducted in Mexico during COVID-19 found that women reported fear of violence as a hindrance to positive wellbeing experiences when visiting urban parks [Huerta and Cafagna, 2021, as cited in Nigg et al. (18)].

4.2.2. Physical characteristic for designing green spaces in pandemics

The studies related to older adult activity show that throughout the pandemic, individuals attended parks for various activities, including sightseeing, strolling, exercising, and jogging. The purpose of such activity was to enhance their mental wellbeing, and the presence of greenery was a crucial component in attracting older adults. The landscape of parks, particularly the plants, played a significant role in this regard, as evidenced by the popularity of cherry blossoms in Olympic Forest Park, lotus flowers, and red leaves in Xishan National Forest Park (21). Incorporating seasonal activities such as flowering plants in different seasons, such as peach and cherry blossoms in the spring, lotus flowers in the summer, colorful leaf plants in the autumn, and fruit plants in the winter, was reported to enhance the appeal of these spaces. Furthermore, a significant amount of greenery in open spaces has been shown to affect the frequency of visits and overall wellbeing among older adults.

The desirability of a neighborhood for older adults is influenced by the distribution, quality, and accessibility of green spaces (79). The proximity of residential areas to urban parks and forests increases the inclination to visit these green spaces for sports or entertainment. Setiowati et al. (79) found that the frequency of visits by individuals residing within 500 meters of a park is associated with the opportunity for exercise. Still, the relationship between distances of 500 and 1,000 m has not been extensively studied. Proximity to green spaces significantly impacts the popularity and frequency of visits to these areas near residential zones (67). Restricting access to high-risk areas like playgrounds and sports facilities while allowing access to pathways and open spaces can reduce the risk of infection, promoting social distancing (34). Conversely, people's willingness to travel long distances to connect with nature in more attractive environments is evidenced by their visits to parks outside their residential areas (67).

Ye and Qiu (48) discovered a correlation between population density and the number of visits to urban green spaces. People living in areas with ample green space are more likely to utilize parks and other open green spaces, such as tree-lined streets, bike paths, or greenways. Suppose individuals allocate less time to visit green spaces in areas with limited green areas due to population density. In that case, it may lead to disparities in reducing physical activity and leisure time in the neighborhood, especially among older adults (48).

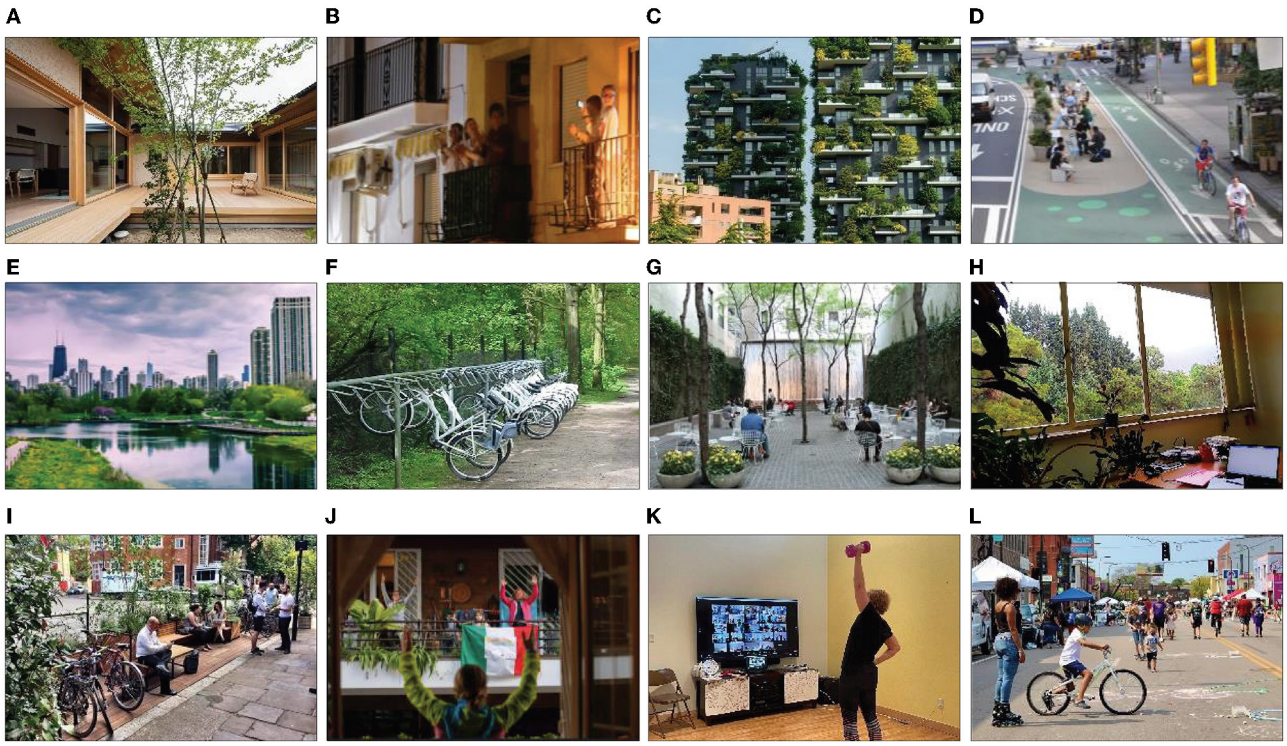

FIGURE 4
(A–L) are related to the design implications.

A study proposed the "Urban Meteoropathy" planning tool for high-density cities like Macau Peninsula, suggesting the implementation of multiple layers of greening on the ground, walls, and rooftops of buildings to address the lack of green spaces [Min et al., 2011, as cited in Ali et al. (30)]. To enhance social cohesion [Figure 4A; Choi and Matz-Costa, 2018, as cited in Levinger et al. (1)], safety, and security in neighborhoods, it is recommended to design houses with access to courtyards [Figure 4B; Lin et al., 2014, cited in Berdejo-Espinola et al. (20)], green spaces (Figure 4C) (66), patios, and outdoor spaces. Strengthening pedestrian and bicycle infrastructure (Figure 4D) (61) and establishing connections between green infrastructure and the urban landscape is crucial (Figure 4E) (48). Green spaces should be strategically located in walkable areas rather than primary nodes and traffic links. Effective management and maintenance of natural public spaces (66) involve considering visitor numbers, maintaining facilities, continuous monitoring, and evaluation. Sufficient funds and the collective participation of stakeholders are needed to adopt and implement nature-oriented policies. Additionally, increasing bicycle parking availability in parks and green spaces is beneficial (Figure 4F) (80).

Finally, urban planners and designers can enhance the green space experience, especially during the pandemic, by creating green walls, small parks, and gardens (Figure 4G) (66), and incorporating elements like color, plants, and sky views, and artwork to improve the indoor environment (Figure 4H) (15). Converting parking lots into parklets and using vacant lots for green spaces is also recommended [Figure 4I; (25); Hanzl, 2020; Liu and Wang, 2021; Sivak et al., 2021, as cited in Labib et al. (66)]. Implementing different mental and physical activities (Figure 4J), such as planting and maintaining plants, changing daily schedules, and adapting to conditions (22), exercise monitoring programs and offering medical consultations have proven beneficial [Figure 4K; Chen et al., 2021, cited in Oliveira et al. (35)]. During emergencies, measures like controlling entry and establishing age requirements are essential, as is organizing for vulnerable populations. Also, to increase access to parks and green spaces, the surrounding or connecting streets can be designated as open streets (Figure 4L) (80). Improving connectivity through wind corridors, high-rise buildings, and considering land shape can enhance urban green and blue spaces while influencing air conditioning. To mitigate risks in densely populated urban areas, it is necessary to separate green-blue spaces and establish dedicated wind corridors physically.

4.3. Future studies

Our goal was to investigate the impact of green spaces on older adults' wellbeing during the COVID19 pandemic. In the next studies, these benefits and effects can be examined in different socio-economic and cultural conditions. It is also possible to check how the policies of different countries have responded to the needs of older people during the pandemic.

5. Conclusion

This study draws upon available studies to identify the individual characteristics of older adults and their living environment to see the effects of the pandemic on the health of the older adult. Moreover, this study examines the qualities of green spaces, the benefits of using green spaces, the types of spaces used by older adults, and the desirable activities of the older adult in the green space during the COVID pandemic. This narrative review study highlights the substantial and enduring impact of the coronavirus on the physical and mental wellbeing of older adults. It also reveals that there is a strong relationship between the surrounding green environment and the incidence of physical problems, anxiety, and depression symptoms among the older population. In addition, in the lived experience of older adults, there was a positive encounter with the condition of the disease, which included sub-themes such as facing the crisis of acceptance and inflexibility in difficult conditions, which made the older adult adapt to the conditions related to the spread of Corona.

According to the findings, there are several stakeholders and experts, including urban planners, health professionals, local communities, and lawmakers, who may collaborate to develop successful strategies to improve people's quality of life. Officials, designers, and urban planners should consider the following measures to help reduce crises:

- Enabling access to and promoting the use of green and open spaces in various dimensions to alleviate overcrowding,
- Enhancing the quality of green spaces by improving biodiversity and tree diversity in urban areas,
- Strengthening pedestrian and bicycle paths to enhance mobility, reduce inequality, promote physical activity, and facilitate access to urban and green areas,
- Developing public and semi-public spaces to foster social interactions and cohesion within neighborhoods,
- Establishing private or shared green spaces, such as terraces and patios, to encourage activity and communication and improve the physical and mental health of the older adult,
- Enhancing neighborhood safety and security while simultaneously strengthening social capital,
- Utilizing mass media to disseminate relevant information,
- Prioritizing health measures and providing access to medical consultations, and
- Focusing on public transportation networks and their ability to minimize risks and injuries, especially for the older adult.

As the global population continues to age, there is an urgent need for further research in the field of the physical and mental health of older adults. This is particularly crucial in the context of urban environments, where the majority of the population resides, and where environmental factors can significantly impact health outcomes. To effectively address the challenges facing the older adult population, it is critical to understand the influence of various environmental variables on their physical and mental health.

Author contributions

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

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.2023.1218091/full#supplementary-material

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The active aging level of the rural older adults with disability in China: a cross-sectional study

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Background: Active aging has been listed as an important indicator to measure the quality of life of the older adults and the construction of the senior care system. There is an imbalance between the supply and demand of senior care services for the disabled older adults in rural areas, and the quality of life needs to be improved.

Objectives: We aimed to analyze the current situation of active aging and the influencing factors of the rural disabled older adults, in order to provide a reference basis for improving the quality of life of the rural disabled older adults.

Methods: We conducted a multicenter and cross-sectional study, using the Barthel Index Scale and Chinese version of the Active Aging Scale, to facilitate the selection of 304 rural older adults with disability in 26 villages under Henan Province for a questionnaire survey.

Results: The mean score for the level of active aging of rural older adults with disability was 1.87 (SD 0.36), with the highest score for the dimension of being self-reliant (Mean2.29, SD 0.61) and lower scores for the dimension of active contribution to society (Mean 1.37, SD 0.55) and building up financial security (Mean 1.37, SD 0.57). The results of the multiple regression analysis showed higher levels of active aging among the disabled older adults with retirement pay, mild disability, and longer time per activity/rehabilitation exercise ($p < 0.05$).

Conclusion: Active aging of the rural disabled older adults is at a low level, with insufficient economic security and social participation. The national government should help improve the quality of primary health care in rural areas, build a friendly environment for senior communities, and improve policies to protect the welfare of the older adults, so as to collaboratively empower the disabled older adults in rural areas at three levels: health, participation, and protection.

KEYWORDS

aging, older adults, disability, active aging, health aging, quality of life

1. Introduction

The number and proportion of older people in countries around the world is on the rise, with the number of people over 60 increasing from 1 billion to 1.4 billion between 2020 and 2030, and the number of people over 60 expected to increase to 2.1 billion in 2050, and the number of people over 80 tripling to 426 million, with the greatest trend of change in low-and middle-income countries (1). China's seventh census data show that by 2020 China's older adults aged 60 and above has reached 264 million (2), the scale of disabled older adults has reached

6.18 million, the proportion of disabled older adults in rural areas reached 50.16%, the disablement rate of rural older adults reached 2.86%, which is 0.58% higher than that in urban areas (3), the phenomenon of aging and disablement in rural areas is serious and has gradually become the strategic focus of the country to actively deal with the problem of aging population.

In 2002, the World Health Organization officially introduced the concept of active aging and defined active aging in its Global Report on Aging and Health as "the process of optimizing the health, social participation and security opportunities of older adults in order to improve their quality of life (4). Active aging has been recognized by the international community as a fundamental initiative to address population aging (5). The European Union, as the regional international organization that has used and studied the concept of active aging the most and the earliest, has further validated the feasibility and socio-economic benefits of active aging strategies by transforming policy advocacy into concrete policy actions based on coordination among member states (6). In addition, establishing the perception of active aging has been proven to improve physical function, cognitive function, mental health, social health and sleep status of older adults (7).

In 2017, China issued the "13th Five-Year Plan for the Development of the National Aging Career and the Construction of the Pension System," which listed active aging as an important indicator for measuring the quality of life of the older adults and the construction of the pension system (8). In 2021, the "Outline of the 14th Five-Year Plan for National Economic and Social Development and Vision 2035" established the national strategic position of actively coping with population aging (9). In order to implement this national strategy, the "Opinions on Strengthening the Work on Aging in the New Era" issued by the Central Committee of the Communist Party of China and the State Council put forward a number of macroscopic guidelines on the senior care service system, health support system, social participation of the older adults and silver hair economy, and emphasized the need to integrate the concept of active aging and healthy aging into the whole process of economic and social development, advocate the implementation of mutual aid and medical and nursing care models, and strengthen long-term care services and protection for the disabled older adults (10). However, there are still many dilemmas in the actual operation of the combined medical and nursing care and mutual care models in rural China, such as incomplete integration of resources, lack of nursing professionals, and difficulties in building organizational support (11, 12). Additionally, multiple factors such as lack of medical care, financial difficulties, age discrimination and social exclusion also seriously hinder the development of active aging in rural areas (13).

Health, participation, and security are the three pillars of active aging. Rural older adults with disability have declining physical functions, lack of health knowledge, cognitive bias, weak awareness, limited social and productive participation (14), lack of adequate protection of their rights and interests in material economy, medical assistance, spiritual and cultural life (15), and low level of well-being and self-assessed health (16). However, the rural older adults with disability have strong needs in terms of health knowledge, social participation, and social security, and a comprehensive assessment is urgently needed to improve their active aging (17). Currently, there is an increasing number of studies on active aging, which mainly focus on policy exploration, pathways and multidimensional factor analysis at the theoretical level (18, 19), and related intervention studies are mostly focused on older adults in urban communities, but less benefit older adults in rural and remote areas, and only the research team has conducted a qualitative study focusing on the level of active aging of older adults with disability in rural areas (17). Therefore, this study combines the qualitative research results of the previous research group and adopts quantitative thinking to investigate the current status of active aging of rural disabled older adults on a large scale, in order to provide a reference basis for improving the rural senior care service system.

2. Materials and methods

2.1. Study design and participants

This study used a multicenter and cross-sectional survey research design. From July to December 2022, a random number table method was used to select three prefectures from 17 prefectures in Henan Province, China, as the study site, and subsequently to facilitate the selection of questionnaires from 26 administrative villages under them for the older adults with disability. Inclusion criteria: ① ≧60 years old; ② Have rural household registration in China and have lived in the local area for at least 1 year; ③ Barthel index (BI) assessment <100 points, those with partial or total loss of self-care ability; ④ No serious visual–auditory or communication dysfunction; ⑤ Informed consent and voluntary participation in this study. Disabled rural older adults with severe mental illness or cognitive dysfunction who were unable to cooperate with the survey were excluded. We used the empirical method to calculate the sample size, which involved a total of 19 demographics variables and 7 active aging variables in this study, taking 5–10 times the number of variables, and then considering a 10–20% missed visit rate, the calculated sample size range was 144–325.

2.2. Measures

2.2.1. Demographics

Participants reported their gender, age, ethnicity, religion, education level, marital status, number of children, residence status, economic source, monthly income (RMB), medical expenses/month, form of medical insurance, level of disability, length of disability (years), and reason for disability. The researchers also collected the status of rural health activity facilities, the number and length of activity/rehabilitation exercises for the disabled older adults, and the degree of family support for the disabled older adults to participate in social activities.

2.2.2. Barthel Index Scale

The Barthel index (BI) scale consists of 10 items: eating, bathing, grooming, dressing, bowel control, urinary control, toileting, bed and wheelchair transfer, level walking, and stair climbing, and is scored out of 100 according to the degree of assistance the patient needs to complete each item (independent, partially assisted, extremely assisted, and totally dependent). Rural older adults with disability are classified into three levels based on BI scores: 61–99 mild disability, 41–60 moderate disability, and 0–40 severe disability. The BI scale is

simple to use and has high sensitivity and reliability, with a retest reliability of 0.89 and inter-rater reliability greater than 0.95, and has been widely used to assess patients' ability to perform activities of daily living (20).

2.2.3. Active Aging Scale

The Active Aging Scale (AAS) was developed by Thai scholar Thanakwang et al. (21) based on the theory of active aging, and research team member Jiange et al. (22) used the Brislin translation model (23) to translate, back-translate, and culturally adapt the scale based on the authorization of the original authors, and revised the item presentation by combining the results of cognitive interviews with rural older adults to form the Chinese version of the Active Aging Scale, which is used to measure the level of active aging of rural older adults with disability. AAS contains 7 dimensions: being self-reliant (7 items), active learning and social integration (8 items), growing spiritual wisdom (5 items), building up financial security (4 items), maintaining healthy lifestyle (5 items), active contribution to society (4 items), and passing on filial piety by example (3 items). 36 items were evaluated on a 4-point Likert scale with a total score range of 36–144, with higher scores indicating higher levels of active aging. The Chinese version of the AAS has good reliability and validity, the scale content validity index (S-CVI/Ave) is 0.981, the content validity index of each item (I-CVI) is 0.83 ~ 1.00, the Cronbach's alpha coefficient is 0.932, the Cronbach's alpha coefficient of each dimension is in the range of 0.777–0.913, and the retest reliability is 0.725.

2.3. Data collection

Data collection was conducted by three graduate students (YTT, YWY, HZZ) trained in uniform questionnaire distribution, using on-site distribution of paper versions of the questionnaires. First, the research team mentor (YZ) contacted the township health centers under the three local municipalities to obtain support and informed consent, and then entered each rural area under the leadership of a member of the township health center, accompanied by a village doctor to conduct a questionnaire survey in the households. Then we introduced the purpose and method of the study to the rural older adults with disability and distributed the questionnaires on site. The graduate students uniformly read the questionnaire entries to the older adults with disabilities in a neutral manner and assisted them in checking the boxes, which were collected immediately after completion, and all questionnaires were surveyed anonymously. After 5 months of survey, a total of 308 questionnaires were returned, of which 304 were valid, with a valid questionnaire return rate of 98.7%.

2.4. Statistical analysis

We conducted all data entry and statistical analysis using SPSS 25.0 (SPSS Inc., Chicago, IL, USA), with categorical data described by frequency and percentage and continuous data described by mean and standard deviation (SD). We also reported the minimum, maximum, and 95% confidence intervals for the mean of each dimension score. Additionally, we applied Q-Q plots to test for normality and the results showed that the outcome variable data points were normally distributed around the diagonal. Two independent samples t-test was used to compare the means of two groups, and one-way ANOVA was used to compare the means of three or more independent samples, and Bonferroni method was chosen for chi-square and Tamheni method and reference Welch test correction results were chosen for chi-square. Furthermore, we used multiple linear regression for impact factor analysis with a significance level of 0.05.

3. Results

3.1. Participants' characteristics

The 304 rural older adults with disabilities ranged in age from 60 to 92 (Mean 71.84, SD 8.23) years, BI score from 10 to 95 (Mean 69.72, SD 19.02) and length of disability from 1 to 40 (Mean 6.17, SD 5.40) years, and all of the disabled older adults suffered from different conditions of chronic diseases, in order of prevalence: hypertension (203/66.8%), neurological diseases (181/59.5%), joint pain (125/41.1%), diabetes mellitus (57/18.8%), coronary heart disease (41/13.5%), cataract (23/7.6%), gastritis (20/6.6%), respiratory diseases (12/3.9%), hyperlipidemia (9/3.0%), etc., with specific demographic information shown in Table 1.

3.2. The scores of active aging level of rural disabled older adults

The mean score of the active aging level of the rural disabled older adults was 67.38 (SD 13.11) and the mean score of the items was 1.87 (SD 0.36), which was at a low level, and the specific scores of each dimension are shown in Table 2.

3.3. Intergroup comparison of active aging level of rural disabled older adults

There was a statistical difference in the scores of active aging level of rural older adults with disabilities by "education level, residence status, economic source, monthly income (RMB), medical expenses/month, medical insurance form, disability level, length of disability (years), number of activities/rehabilitation exercises, length of activities/rehabilitation exercises/time, and degree of family support for the disabled older adults to participate in social activities"($p < 0.05$), as shown in Table 1. The results of the two-by-two comparison between groups showed that the active aging level of the disabled older adults in primary school and below was lower than that of those in junior high school, those living with children were lower than those living with children and spouses and those living alone, those living with spouses were lower than those living alone, and those on government assistance were lower than those on other (working, farming, etc.) economic incomes ($p < 0.05$). The higher the monthly income and the lower the degree of disability, the better the active aging level of the older adults, those with retired salary were higher than those with other economic sources, those with monthly medical expenses of 100 or more were significantly higher than those with 500 or more, those with length of disability of 1 year or more were significantly higher than those with 5 and 10 years or more, and those with 15 years or more were significantly higher than those with

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TABLE 1 Intergroup comparison of active aging level of rural disabled older adults.

Characteristics	*n*(%)	Mean	SD	*F*/*Z*	*P*
Gender				−0.703*	0.482
Male	156 (51.3%)	67.69	13.80		
Female	148 (48.7%)	67.05	12.39		
Age				1.771**	0.156
60~	66 (21.7%)	68.44	9.77		
65~	132 (43.4%)	65.67	11.89		
75~	49 (16.1%)	67.47	17.61		
80~	57 (18.8%)	70.00	14.42		
Ethnicity				−0.418*	0.616
Han ethnic group	298 (98.0%)	67.42	13.23		
Ethnic minorities	6 (2.0%)	65.00	3.10		
Religion				0.234*	0.815
None	224 (73.7%)	67.29	13.73		
Yes	80 (26.3%)	67.61	11.29		
Education level				5.145**	0.006
Primary school and below	257 (84.5%)	66.36	13.20		
Junior high school	44 (14.5%)	73.00	11.27		
High school and above	3 (1.0%)	72.00	12.12		
Marital status				0.430**	0.731
Unmarried	4 (1.3%)	68.75	7.09		
Married	220 (72.4%)	67.57	12.84		
Divorced	5 (1.6%)	61.00	8.22		
Widowed	75 (24.7%)	67.15	14.39		
Number of children				0.381**	0.767
0	7 (2.3%)	64.57	7.23		
1	14 (4.6%)	66.57	15.01		
2	78 (25.7%)	66.38	11.86		
3~	205 (67.4%)	67.90	13.62		
Residence status				3.302**	0.011
Living with children	57 (18.8%)	63.67	14.71		
Living with spouse	109 (35.9%)	66.19	12.06		
Living with children and spouse	209 (35.9%)	69.51	13.21		
Living alone	7 (2.3%)	77.43	6.27		
Nursing home	22 (7.2%)	69.05	11.90		
Economic sources				23.882**	<0.001
Retirement pay	23 (7.6%)	86.30	10.10		
Child support	88 (28.9%)	64.58	13.95		
Government relief	48 (15.8%)	63.90	11.16		
Pension	113 (37.2%)	65.61	9.39		
Other (part-time work, farming, etc.)	32 (10.5%)	72.91	14.32		
Monthly income (RMB)				22.899**	<0.001
<500	193 (63.5%)	65.56	11.30		
500~	94 (30.9%)	67.64	13.91		
1000~	17 (5.6%)	86.53	12.94		

(Continued)

TABLE 1 (Continued)

Characteristics	*n*(%)	Mean	SD	*F*/*Z*	*P*
Medical expenses/month				4.570**	0.012
<100	69 (22.7%)	66.41	12.42		
100~	160 (52.6%)	69.36	13.30		
500~	75 (24.7%)	64.03	12.71		
Medical insurance form				−2.301*	0.021
Urban employee medical insurance	7 (2.3%)	78.00	10.94		
Urban and rural residents' medical insurance	297 (97.7%)	67.12	13.07		
Disability level				107.139**	<0.001
Mild disability	219 (72.0%)	71.06	11.74		
Moderate Disability	46 (15.1%)	63.15	12.40		
Severe Disability	39 (12.8%)	51.64	6.61		
Length of disability (years)				11.059**	<0.001
1~	150 (49.3%)	70.36	13.20		
5~	61 (20.1%)	63.75	14.24		
10~	51 (16.8%)	60.33	10.81		
15~	27 (8.9%)	68.41	6.36		
Reason for disability				0.524**	0.596
Disease	247 (81.3%)	66.99	12.15		
Accident	24 (7.9%)	68.96	21.84		
Aging	33 (10.9%)	69.12	11.97		
Number of activities/rehabilitation exercises				33.711**	<0.001
Never	113 (37.2%)	58.92	11.42		
Once a month	36 (11.8%)	65.44	7.27		
2 ~ 4 times a month	28 (9.2%)	68.79	8.04		
2 ~ 3 times a week	67 (22.0%)	76.54	10.05		
More than 4 times a week	60 (19.7%)	73.57	13.67		
Activity/rehabilitation exercise hours/time				32.814**	<0.001
Never	113 (37.2%)	58.92	11.42		
Under 30 min	123 (40.5%)	68.98	9.37		
30 min~	39 (12.8%)	74.10	9.44		
1 h~	17 (5.6%)	84.12	11.40		
2 h~	12 (3.9%)	84.92	15.64		
Degree of family support for the disabled older adults to participate in social activities				25.837**	<0.001
Highly unsupportive	14 (4.6%)	49.00	9.55		
Unsupportive	33 (10.9%)	63.67	10.54		
Normal	98 (32.2%)	61.92	9.24		
Supportive	116 (38.2%)	72.89	12.40		
Highly supportive	43 (14.1%)	73.77	13.82		

*Z-value; **F-value.

10 years or more ($p < 0.05$). The level of active aging was significantly higher for the disabled older adults with activity/rehabilitation exercise 2–3 times per week than for those who never, 1 time per month, and 2–4 times per month, and for those with activity/rehabilitation exercise 1 h or more than for those who never, less than 30 min, and 30 min or more ($p < 0.05$).

3.4. Influencing factor analysis of active aging level of rural disabled older adults

Taking the score of active aging level of rural disabled older adults as the dependent variable, and taking the statistically significant variables in the comparison between groups as the independent

variables, multiple linear regression analysis was performed after assigning values to the independent variables, as shown in Table 3. The results showed that the four independent variables "economic source, disability level, activity/rehabilitation exercise hours/time" entered the regression equation ($F = 23.596$, $R = 0.773$, $R^2 = 0.597$, DW = 1.815, VIF < 10), see Table 4 for details.

4. Discussion

The active aging of rural older adults with disability is at a low level, and the level of economic security and social participation need to be improved. Economic source, disability level, and activity/rehabilitation exercise hours/time are the influencing factors of the level of active aging of rural older adults with disability ($p < 0.05$).

The total score of 67.38 (SD 13.11) for active aging among rural older adults with disability is lower than the findings of Huiying et al. (24) for rural older adults, which may be related to the fact that the rural older adults with disability surveyed have reduced activities of daily living (ADLs) and all suffer from different conditions and numbers of chronic diseases, mostly hypertension, neurological diseases and joint pain, which to a certain extent reduce the level of active aging among the older adults with disability. The health and community mobility of older adults is somewhat reduced, limiting the level of active aging (25). Xuelian et al. (26) demonstrated that declining ADL reduces active aging in older adults, that depression is a mediating influence, and that comorbid depression and declining ADL have a cumulative effect on active aging. Siltanen et al. (27) found lower levels of active aging in older adults with mobility impairments and that psychological flexibility could mitigate the negative effects of early walking difficulties on active aging. Furthermore, health literacy can help older adults with disability cope with illness and functional limitations and maintain a high level of active aging (28). Diverse applications of information and communication technology (ICT) can reduce isolation and enhance social participation of the older adults with disability. However, in the process of urbanization, the investment and resource distribution of senior care in rural areas are lower than those in cities, and the traditional perception of senior care makes the lack of organizational atmosphere for social participation of older adults in rural areas (29), the lack of active health behavior of disabled older adults and the prominent phenomenon of digital divide (30), which seriously restrict the process of active aging in rural areas. This suggests that we should build a rural and aging-appropriate information technology platform according to the current situation of electronic health literacy of the disabled older adults in rural areas, and integrate virtual reality and augmented reality technologies to conduct health lectures, train memory or perform rehabilitation exercises to increase the health knowledge reserve of the disabled older adults and enhance their dynamic interaction with the surrounding environment (31).

The highest score of 2.29 (SD 0.61) for the being self-reliant dimension of rural older adults with disability is consistent with the findings of Celmira et al. (32) and Hongjie et al. (33) for rural older adults, which may be related to the fact that 72.0% of the surveyed older adults are in a mild state of disability, and the lack of adequate human resources for the disabled due to the shortage of family caregivers in rural areas, coupled with the fact that the disabled older adults do not want to bring financial and caregiving burdens to their families, they still actively try to cope with daily activities independently and insist on doing the work they can. The lowest score of the active contribution to society (Mean 1.37, SD 0.55) dimension indicates that the social participation of the older adults with disability in rural areas is poor. The reason for this may be that the physical functional impairment of the older adults with disability is very likely to make them have low self-esteem and even close themselves off, avoiding or refusing social interactions, decreasing the mobility of their living space, and feeling that they have no experience and skills to pass on to others (34). Sariyamon et al. (35) found that the level of community friendly environment and healthy lifestyles were contributing factors to active aging among older adults. Two community empowerment factors, leisure and welfare facilities for older adults and cooperative alliances, were significantly associated with active aging (36). This suggests that village councils should actively create a caring community environment for the older adults, such as age-friendly renovation of neighborhoods, improving the hygiene of outdoor spaces (37), integrating multiple resources to provide regular home visits, or creating virtual health and age-friendly environments based on ICT to reduce social isolation and promote social participation (38).

The economic source was an influential factor in the level of active aging of rural disabled older adults, consistent with the findings of Huiying et al. (24). The highest level of active aging ($p < 0.05$) was found among the disabled older adults with retirement pay, who were mostly village workers returning to their hometowns, with higher education and monthly income overall, better health literacy and active health behaviors, and with sufficient financial security to reduce the psychological stress and financial burden of the disabled older adults, supporting their access to better material and health services and promoting a positive mindset toward social participation (39, 40). But only 7.6% of the rural disabled older adults had a retirement salary, and their main sources of financial support were still pension (37.2%), child support (28.9%) and government relief (15.8%), which indicates that the national pension welfare policy has gradually become the main financial security for the rural disabled older adults. Rural older adults with disability who relied on part-time work and farming to generate income accounted for 10.5% of the total, and their active aging scores were higher than those on government relief ($p < 0.05$). This may be related to the better overall physical and psychological health of the disabled older adults who engage in productive participation (41). However, the average score of building up financial security dimension for rural older adults with disability was only 1.37 (SD 0.57), with 63.5% of the older adults with disability had a monthly income of less than 500 (RMB), but 24.7% of the older adults with disability had monthly medical expenses of more than 500 (RMB), and their financial income microblogging and inability to make ends meet were obvious, and their overall financial security was not sufficient. This can be attributed to the weakened self-working capacity of the disabled older adults, reduced productive participation and economic income generation (14), weakened economic contribution to the family, and increased levels of depressive symptoms, which can easily lead to negative changes in aging attitudes (42). The national government should accelerate the implementation of long-term care insurance and medical assistance insurance for major diseases in rural areas, provide re-employment opportunities for the older adults with the ability to participate in production from the perspective of poverty alleviation, organize rural third-age

TABLE 2 Total and average scores of active aging level of rural disabled older adults.

Active aging level	Maximum points	Minimum points	Total scores		Average scores		95% CI	
			Mean	SD	Mean	SD	Lower border	Upper border
Being self-reliant	26	7	16.04	4.24	2.29	0.61	15.56	16.52
Active learning and social integration	23	8	12.92	3.64	1.61	0.45	12.51	13.33
Active contribution to society	15	4	5.49	2.19	1.37	0.55	5.24	5.74
Growing spiritual wisdom	16	5	10.02	2.83	2.00	0.57	9.70	10.34
Building up financial security	16	4	5.50	2.27	1.37	0.57	5.24	5.75
Maintaining healthy lifestyle	20	5	10.81	3.02	2.16	0.60	10.46	11.15
Passing on filial piety by example	11	3	6.60	1.43	2.20	0.48	6.44	6.76

universities to teach health knowledge (43), and gradually improve and implement the national welfare policy for the older adults.

The degree of disability was a negative predictor of the level of active aging among rural disabled older adults ($p < 0.05$), consistent with the results of the analysis by Hairu et al. (44). Decreased self-care can be a barrier to daily living and socialization, causing a passive reduction in the level of social participation and even negative emotions in older adults (45). A study by Sini et al. (46) confirmed that decreasing social distance reduces the chances of older adults to lead an active life. In this study, 69.4% of the older adults had been disabled for less than 5 years, 49.3% had become disabled within the last year, and 81.3% were disabled due to illness. The physical status of the older adults with short-term disability is still in the recovery stage, their physiological, role and self-concept adaptation levels are low, their overall health status is poor, and their healthcare needs are diverse (47). However, rural primary health care resources are limited, and home-bound disabled older adults only enjoy basic public health services and lack professional guidance and treatment at the health level, which to a certain extent affects their level of active aging (48). This indicates that the level of comprehensive primary health care in rural areas needs to be improved. Consider using the "Internet+" channel to help push active aging, promote the sinking of quality medical resources through medical associations/medical communities, and integrate multiple resources to provide personalized consultation and health promotion services (49). Reyhane et al. (50) provided a six-week health education component (once a week) on nutrition, physical activity, responsibility, stress management, communication and spirituality to older adults, demonstrating that training based on a health-enhancing approach can be effective in promoting active aging in older adults.

The longer the duration of each activity/rehabilitation exercise, the higher the level of active aging in rural older adults with disability, and 2–3 exercises per week for 1 h and more was a better activity/rehabilitation dose ($p < 0.05$). Sport/rehabilitation exercise is a health-level social participation that increases contact and communication with the outside world, and prolonged, regular exercise can help older adults with disability to improve their physical fitness, prevent or mitigate the negative effects of disease, and improve cognitive function (51, 52). Moreover, older adults with disability who actively participate in village activities or rehabilitation exercises tend to have better health awareness and active social participation, and higher levels of subjective well-being (53). However, there are still 37.2% of the disabled older adults never participate in activities and rehabilitation exercises, which may be related to the older adults' fear of falling, and 47.7% of the surveyed disabled older adults' family members do not support their participation in social activities, coupled with the low level of professional treatment in rural areas and the lack of rehabilitation specialists in rural health centers, resulting in the inability of the disabled older adults to obtain professional rehabilitation guidance and medical assistance. The negative impact on the participation of the older adults in activities (54). It suggests that grassroots governments should strengthen the construction of village activity facilities, actively mobilize the participation of multiple subjects such as village committees, kindergartens and volunteer associations, and organize multimodal social activities through channels such as jitterbug, radio and village stages (55). Silvia et al. (56) used new technology to create "scavenger hunts" to promote physical activity, where participants use a receiver GPS to hide or find real or virtual objects, adding gamification to self-tracking to promote participation and active aging in older adults. Furthermore, the role of "health mentors" can be established in villages to enhance the active aging of rural older adults with disability through the establishment of senior learning communities and intergenerational-based learning.

5. Conclusion

Rural older adults with disability have a low level of active aging and insufficient financial security and social participation. Rural older adults with moderate to severe disability are a key concern for the government in actively addressing population aging. The national government should actively improve older adult welfare policies to enhance economic security, promote the construction of medical associations/medical communities to improve the quality

TABLE 3 Independent variable assignment.

Independent variable	Assignment method
Education level	1 = Primary school and below, 2 = Junior high school, 3 = Junior high school
Residence status	Dummy variables were set using "living with children" as the control group: Living with children ($Z_1 = 0$, $Z_2 = 0$, $Z_3 = 0$, $Z_4 = 0$), Living with spouse ($Z_1 = 1$, $Z_2 = 0$, $Z_3 = 0$, $Z_4 = 0$), Living with children and spouse ($Z_1 = 0$, $Z_2 = 1$, $Z_3 = 0$, $Z_4 = 0$), Living alone ($Z_1 = 0$, $Z_2 = 0$, $Z_3 = 1$, $Z_4 = 0$), Nursing home ($Z_1 = 0$, $Z_2 = 0$, $Z_3 = 0$, $Z_4 = 1$)
Economic sources	Dummy variables were set using "retirement pay" as the control group: Retirement pay ($Z_1 = 0$, $Z_2 = 0$, $Z_3 = 0$, $Z_4 = 0$), Child support ($Z_1 = 1$, $Z_2 = 0$, $Z_3 = 0$, $Z_4 = 0$), Government relief ($Z_1 = 0$, $Z_2 = 1$, $Z_3 = 0$, $Z_4 = 0$), Pension ($Z_1 = 0$, $Z_2 = 0$, $Z_3 = 1$, $Z_4 = 0$), Other (part-time work, farming, etc.) ($Z_1 = 0$, $Z_2 = 0$, $Z_3 = 0$, $Z_4 = 1$)
Monthly income (RMB)	1 = <500, 2 = 500~, 3 = 1,000~
Medical expenses/month	1 = <100, 2 = 100~, 3 = 500~
Medical insurance form	1 = Urban employee medical insurance, 2 = Urban and rural residents' medical insurance
Disability level	1 = Mild disability, 2 = Moderate Disability, 3 = Severe Disability
Length of disability (years)	1 = 1~, 2 = 5~, 3 = 10~, 4 = 15~
Number of activities/rehabilitation exercises	1 = Never, 2 = Once a month, 3 = 2 ~ 4 times a month, 4 = 2 ~ 3 times a week, 5 = More than 4 times a week
Activity/rehabilitation exercise hours/time	1 = Never, 2 = Under 30 min, 3 = 30 min~, 4 = 1 h~, 5 = 2 h~
Degree of family support for the disabled older adults to participate in social activities	1 = Highly unsupportive, 2 = Unsupportive, 3 = Normal, 4 = Supportive, 5 = Highly supportive

TABLE 4 Multiple regression analysis results on the level of active aging of rural disabled older adults.

Variable		Partial regression coefficient	Standard error	Standardized regression coefficient	*t*	*P*
Constant		60.855	9.747	–	6.244	<0.001
Economic sources "Retirement pay" as the control group	Child support	−13.176	2.854	−0.453	−4.617	<0.001
	Government relief	−17.828	2.818	−0.497	−6.327	<0.001
	Pension	−11.847	2.918	−0.438	−4.059	<0.001
	Other (part-time work, farming, etc.)	−7.494	2.959	−0.179	−2.532	<0.001
Disability level		−5.480	0.809	−0.300	−6.771	<0.001
Activity/rehabilitation exercise hours/time		4.404	0.939	0.355	4.691	<0.001

of rural primary health care, create a virtual senior community-friendly environment based on ICT, and innovate multi-modal physical exercise activities to promote social participation of the disabled older adults. However, this study only selected disabled older adults from rural in Henan Province, and the sample size was limited and not representative of the overall level of the disabled older adults in rural areas. Additionally, the questionnaire was completed with the help of the researcher to understand the subjective perceptions of the respondents, and some items such as "chronic diseases suffered" may be biased due to the respondents' lack of knowledge about the diseases.

Data availability statement

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

Ethics statement

The study was approved by the Life Science Ethics Review Committee of Zhengzhou University (ZZUIRB2021–155) and conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). This survey was voluntary, anonymous and completely confidential. The older adults were informed that submitting the completed questionnaire was considered implied consent.

Author contributions

YTT: investigation, data curation, formal analysis, writing - original draft, and writing – review and editing. YZ: conceptualization, resources, methodology, Writing – review and editing, and funding acquisition. YWY: investigation, formal analysis, visualization. HZZ: investigation and data curation. XZL: data curation and formal 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.2023.1219573/full#supplementary-material

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Continuity and changes in grandchild care and the risk of depression for Chinese grandparents: new evidence from CHARLS

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Objectives: Although studies have researched the mental effects of intergenerational care, little is known about the impact of transformations in caregiving intensity on depression. This study explores grand-parents' depressive symptom outcomes in terms of changes over time in grandparental childcare, with considerations for subgroup differences.

Method: Using data from the 2015–2018 China Health and Retirement Longitudinal Study on grandparents aged 45 and older, we adopted generalized estimating equations to estimate the effects of seven category changes [(1) continued to provide high-intensity or (2) low-intensity care at both waves; (3) never provided care; (4) started caregiving; (5) ended caregiving; (6) provided less intensive care; and (7) provided more intensive care] over time in grandparental childcare on depressive symptoms among 17,701 grandparents with at least one grandchild, as well as how the impact varies by gender and urban/rural areas.

Results: Grandparents who decreased the intensity of care, stopped childcare, or offered continuous low-intensity care were associated with a lower level of depression compared with those providing no childcare. In addition, the benefit of continuous caregiving on mental health was especially noticeable in urban grandmothers.

Conclusion: Providing continuous low-intensity, decreased-intensity grand parenting and the cessation of caregiving were associated with a decreased level of depression for Chinese grandparents; however, there were complex interactions at play. Policies aimed at supporting grandparenting should consider caregiving intensity transitions relevant to gender and urban/rural residence.

KEYWORDS

grandchild care, depression, changes in caregiving intensity, rural–urban context, gender norms

1. Introduction

In China, grandparents play increasingly active roles in providing care for their grandchildren (1). Over 50 percent of Chinese middle-aged and older grandparents participate in grandchild care (2). Strong cultural traditions of filial piety and the norm of intergenerational reciprocity promote Chinese grandparents to take on the responsibility of caring grandchildren

(3). Especially in rural areas, large numbers of migrants have left their children in the care of grandparents at home (4). It has been reported that more than a quarter of children in rural China live solely with a grandparent (5). With increased life expectancy, more Chinese grandparents can care for their parents and grandchildren to alleviate the time and financial strain on young couples raising children (6). In this context, the question of whether long-term care activities promote or impair the mental health of older caregivers has attracted scholars' attention.

The impacts of looking after children on grandparents' mental health are controversial. On the one hand, caregiving activities can be a physical burden and limit grandparents' time and opportunities to care for themselves (7) and assume the role of marriage (8), which makes it harder for caregivers to resist emotional stress. On the other hand, grandparents may feel higher life satisfaction, self-efficacy (9) and less depression (10) when increasing intergenerational contact by engaging in caring for grandchildren (11). Moreover, some findings have also demonstrated null effects between caregiving and caregivers' depression symptoms (4).

After controlling for socioeconomic and demographic characteristics, a growing body of literature suggests that the impact of grandparenting on grandparents' depression is contingent on the intensity of parenting and its change and continuity. Some articles highlighted the importance of grandparenting for a moderate level of engagement (12, 13). Only a few articles have deeply researched the effect of dynamic changes in grandparenting on depression. Ku et al. (14) indicated that grandparents who continued to provide care reported fewer depressive symptoms than non-caregivers. However, Di Gessa et al. (15) suggested that there was no significant link in European countries between the change in grandparental childcare and depression symptoms. Such an effect may not be fully detected if there are no measures of care intensity and no strong evidence from the Chinese cultural context.

There has been some literature about the relation between caring for grandchildren and grandparents' depression symptoms. However, apart from using data from America or European countries (15–17), research on grandparenting in China adopted mostly cross-sectional data (18) or longitudinal samples in specific regions (19), which made it difficult to ascertain external validity and the extensibility of the sample. Moreover, previous studies have tended to focus on the health impacts of whether grandparents participate in grandparenting (19) or caregiving intensity (13). Research on how the duration of grandchild care influenced caregivers' health mainly used simple classifications of grandchild care based on whether grandparents provided care (7, 14, 20), which considered little about transformations in caregiving intensity as well as subgroup variations in gender and urban/rural residence (13). Specifically, the variations in measures of care intensity may cause inconsistent analysis results. Some analyses have used the time of providing caregiving, such as weekly (21) and yearly hours (22), to differentiate levels of intensity. Besides, there were inconsistent measures of adopting continuous metrics or categories to be determined as appropriate, such as adopting a continuous variable of caregiving time (23) or providing less or more than 4 h in helping grandchildren per week (21). Other works in the literature employed a functional definition of caregiving status (24).

2. Literature review

2.1. Grandchild care and depressive symptoms

Caregiving can predict the changes in depression symptoms both positively and negatively. Role Accumulation Theory and Role Tension Theory are competing perspectives that have been widely used to study the impacts of grandparenting on mental health. Role Accumulation Theory postulates that multiple social roles are associated with higher life satisfaction and self-efficacy (9) when achieving social integration in different areas (25). As individuals age, retire, and become less socially integrated, the need to strengthen social roles may be greater than ever (26). As a kind of social activity, caring for grandchildren meets intergenerational emotional needs (10) and promotes social integration (27) for grandparents through meaningful engagement. Role Tension Theory, in contrast, suggests that individuals may face role conflicts and role stress when requested to perform specific obligations of different roles (28). Providing childcare may limit grandparents' time and opportunities to care for themselves (29) and assume the role of marriage (8), making them more vulnerable to emotional stress. Furthermore, older people frequently feel unvalued and disrespected as a result of generational conflicts over child-rearing understanding, which is harmful to psychological health (30).

2.2. Rural–urban context and gender norms in China

Rural–urban residence and gender roles shape intergenerational care and depressive symptoms for Chinese grandparents (13). The traditional family division of labour has shaped varied responsibilities between grandmothers and grandfathers. Women are expected to take on more intensive duties such as feeding and cooking, while men usually play a companion role as playmates or helpers (31). In this way, engaging in the care of grandchildren is regarded as a deviation from the norm for men (31). As shown in a previous study, compared with grandmothers, grandfathers suffered from a greater risk of depression when continuously providing high-intensity care (22). However, because women are the main caregivers, some findings showed that the positive mental health outcomes of caregiving were reported significantly only for grandmothers, whereas this was previously thought to be the effect of the whole sample (21, 32). In addition, when considering the intersection of gender roles and the rural–urban context, it may turn out that only urban grandfathers who were financially independent and did not seek an intergenerational time-for-money exchange were associated with fewer depressive symptoms from grandchild care (31). The health effects of continuous caring on gender and urban/rural subgroups have yet to be fully studied.

The consequences of grandchild care are associated with the residence circumstances of the care. First, in recent decades, numerous rural workers have migrated to urban areas, leaving their young children to be cared for by grandparents. It results in rural grandparents having to do more extensive care duties and becoming acclimated to it (1). Second, rural state pension coverage is less extensive than in urban areas, implying that intergenerational care is more of a burden than a reward for rural grandparents (31). This

means that rural grandparents have to shoulder the financial and physical burden of caring for grandchildren (33). Third, the one-child policy, which was enforced more rigorously in urban areas, leads to greater involvement and less burden for urban grandparents (31). Affluent urban grandparents tend to compete for opportunities to nurture and care for shrinking numbers of grandchildren to gain emotional rewards (34). Compared to their urban counterparts, rural grandparents are more dependent on their children's financial support (35–37). In this way, rural grandparents may be more likely to consider grandchild care as a reciprocal form of intergenerational reward rather than an emotionally rewarding activity (33). Forth, rural grandparents could be more likely to become the 'sandwich' generation at a young age and face conflicts between providing care for their parents and grandchildren (38), which may make intergenerational care particularly stressful.

2.3. The present study

Our research contributes to the literature in three ways. First, we used national panel data from China to investigate the relationship between stability and changes in grandparental childcare and depression, expanding on previous studies that were either cross-sectional or had specific region observation windows. Considering that little attention has been paid to the duration and changes of grandparenting on mental health, we classified it based on the intensity of caregiving rather than simple engagement. Second, we adopted generalized estimating equations to estimate the effects of caregiving transitions on depressive symptoms to handle time-dependent autocorrelated data (39). Finally, we performed an exploratory investigation to explore how the relationships between the changes in grandparenting intensity and depression vary between different subgroups of location and gender, while prior studies mostly focused on how the relations differ across gender (40). Based on current evidence, we expect that changes in grandparenting intensity is associated with depression symptoms in later life (Hypothesis 1). Furthermore, the effects of grandparenting change on depression operate differently by gender and urban/rural areas (Hypothesis 2).

3. Method

3.1. Data and sample

The data came from China Health and Retirement Longitudinal Surveys (CHARLS) hosted by the National Development Research Institute of Peking University. CHARLS adopted probability proportional to size sampling to collect a nationally representative sample of Chinese residents aged 45 and above, which included 450 villages in 150 counties and districts throughout China. We obtained national tracking survey data in 2015 and 2018 from the official website.[1] Our analysis was limited to the respondents with follow-up information ($n = 36,274$) above 45 ($n = 34,530$) who reported having at least one grandchild under 16 at baseline ($n = 25,186$) and provided complete answers to the depression level ($n = 21,434$), the independent variable ($n = 18,835$), demographics and family characteristics ($n = 17,701$) in both waves (see Supplementary Figure S1). We compared the differences in socioeconomic characteristics between excluded and retained samples (see Supplementary Table S1), and the retained participants were younger, more males, more rural residences, more at married or cohabiting status, more at fair or good health status, at higher level of individual expenditure, and had higher levels of education, which also showed up in other similar studies (39, 41). Our samples were not significantly different in depressive symptoms when compared with the excluded samples, but it may be necessary to be careful to generalize our results.

3.2. Measures

The dependent variable was the level of depression. According to the epidemiology research center Depression Scale (CES-D), respondents were asked to assess their psychological and emotional states within a week. The scale included ten subitems. The 4-point responses were rescaled from little or no (0) to most of the time (3). The total score was between 0 and 30. The higher the score, the more serious the depression. Depression levels were log-transformed to fit a normal distribution of the variables and ranged from 0 to 3.434 (Cronbach $\alpha = 0.77$).

We constructed annual hours of grandparenting to measure the intensity of care and built the classification of changes on that basis. In two waves, respondents with at least one grandchild were asked if they had cared for them in the previous 12 months. If they did, they were asked how many weeks and, on average, how many hours they would have cared for their grandchildren per week in the last year. Using this information, we distinguished between three types of grandparent care: high-intensity care (i.e., those who cared for grandchildren at least 40 h per week on average or for over 2080 h in the last year), low-intensity care (i.e., those who cared for grandchildren for less than 40 h per week on average or under 2080 h last year), and noncaregivers (i.e., those who did not care for grandchildren). We chose 40 h per week for intensive grandparent care because according to the Labor Law of China and previous studies, 40 h per week (five-day working week and no more than 8 h a day) is equivalent to having a full-time job (40, 42). Then, we created a 7-category stability showing the changes in the provision of grandchild care in two waves. We distinguished those who (1) continued to provide high-intensity or (2) low-intensity care at both waves; (3) never provided care; (4) started caregiving (did not care at Wave 1 but provided high-intensity or low-intensity care at Wave 2); (5) ended caregiving (only providing high-intensity or low-intensity care at Wave 1); (6) provided less intensive care (from high-intensity care at Wave 1 to low-intensity care at Wave 2); and (7) provided more intensive care (from low-intensity care at Wave 1 to high-intensity care at Wave 2).

The control variables at baseline included gender (female = 0); location (rural = 0); education level (illiterate = 0; primary school and below = 1; middle school graduation = 2; high school graduation = 3; college and above = 4); marital status (separation, divorce, widowhood, never married = 0; married, cohabiting = 1); self-rated health status (poor = 0; fair =1; good =2); age; whether to live with children (yes = 1); number of grandchildren under the age of 16; number of surviving children; and *per capita* household expenditure.

1 http://CHARLS.pku.edu.cn

TABLE 1 Comparison between subgroups at baseline.

	(1)	(2)	(3)	(4)	(5)	F/χ2
	Mean (SD)/*N* (%)	Mean (SD)/*N* (%)	Mean (SD)/*N* (%)	Mean (SD)/*N* (%)	Mean (SD)/*N* (%)	Significance
Depression	1.903 (0.857)	2.106 (0.814)	1.807 (0.835)	1.845 (0.861)	1.573 (0.899)	141.47***
Changes of caregiving intensity						91.143***
No childcare at either wave	3,056 (33.44)	1,248 (34.46)	1,204 (35.94)	305 (27.31)	299 (28.50)	
High-intensity childcare at both waves	985 (10.78)	408 (11.26)	332 (9.91)	126 (11.28)	119 (11.34)	
Low-intensity childcare at both waves	767 (8.39)	272 (7.51)	254 (7.58)	123 (11.01)	118 (11.25)	
Starting childcare at Wave 2	1,372 (15.01)	527 (14.55)	523 (15.61)	169 (15.13)	153 (14.59)	
Stopped childcare at Wave 2	1,539 (16.84)	631 (17.42)	574 (17.13)	171 (15.31)	163 (15.54)	
High-intensity → Low-intensity childcare	785 (8.59)	295 (8.14)	256 (7.64)	128 (11.46)	106 (10.10)	
Low-intensity → High-intensity childcare	634 (6.94)	241 (6.65)	207 (6.18)	95 (8.50)	91 (8.67)	
Male	4,399 (48.14)	0 (0.00)	3,350 (100.00)	0 (0.00)	1,049 (100.00)	9138.000***
Living in cities	2,166 (23.70)	0 (0.00)	0 (0.00)	1,117 (100.00)	1,049 (100.00)	9138.000***
Education						1728.087***
Illiterate	2,181 (23.87)	1,521 (41.99)	399 (11.91)	210 (18.80)	51 (4.86)	
Primary school and below	4,128 (45.17)	1,562 (43.13)	1728 (51.58)	443 (39.66)	395 (37.65)	
Middle school	1905 (20.85)	437 (12.07)	856 (25.55)	282 (25.25)	330 (31.46)	
High school	825 (9.03)	98 (2.71)	347 (10.36)	160 (14.32)	220 (20.97)	
College and above	99 (1.08)	4 (0.11)	20 (0.60)	22 (1.97)	53 (5.05)	
Married or cohabiting	8,250 (90.28)	3,187 (87.99)	3,120 (93.13)	956 (85.59)	987 (94.09)	98.159***
Self-assessed health status						133.870***
Poor	2,279 (24.94)	1,101 (30.40)	768 (22.93)	242 (21.67)	168 (16.02)	
Fair	4,744 (51.92)	1805 (49.83)	1748 (52.18)	618 (55.33)	573 (54.62)	
Good	2,115 (23.15)	716 (19.77)	834 (24.90)	257 (23.01)	308 (29.36)	
Age in 2015						68.139***
45–60	4,240 (46.40)	1832 (50.58)	1,459 (43.55)	514 (46.02)	435 (41.47)	
60–70	3,638 (39.81)	1,343 (37.08)	1,369 (40.87)	473 (42.35)	453 (43.18)	
70–80	1,132 (12.39)	404 (11.15)	454 (13.55)	125 (11.19)	149 (14.20)	
above 80	128 (1.40)	43 (1.19)	68 (2.03)	5 (0.45)	12 (1.14)	
Living with their children	3,349 (36.65)	1,319 (36.42)	1,173 (35.01)	444 (39.75)	413 (39.37)	11.909**
Number of grandchildren	2.592 (1.803)	2.736 (1.84)	2.777 (1.909)	2.072 (1.44)	2.056 (1.424)	83.52***
Number of children	2.76 (1.304)	2.9 (1.315)	2.855 (1.31)	2.399 (1.244)	2.361 (1.148)	83.22***
Per capita household expenditure	8.85 (1.081)	8.728 (1.084)	8.74 (1.054)	9.181 (1.035)	9.267 (1.032)	310.969***
1st quartile	2004 (21.93)	926 (25.57)	815 (24.33)	142 (12.71)	121 (11.53)	
2nd quartile	2,378 (26.02)	967 (26.70)	910 (27.16)	270 (24.17)	231 (22.02)	
3rd quartile	2,455 (26.87)	954 (26.34)	912 (27.22)	304 (27.22)	285 (27.17)	
4th quartile	2,301 (25.18)	775 (21.40)	713 (21.28)	401 (35.90)	412 (39.28)	
Number of observations	9,138	3,622	3,350	1,117	1,049	

**$p < 0.01$, ***$p < 0.001$. Model (1) to (5) describe samples of all samples, rural grandmothers, rural grandfathers, urban grandmothers, and urban grandfathers in turn.

3.3. Data analysis

We compared the differences of depression levels and other baseline characteristics across four subgroups of rural grandmothers, rural grandfathers, urban grandmothers, and urban grandfathers (see Table 1) and seven category changes over time in grandparental childcare (see Supplementary Table S2), including the chi-square test and variance (ANOVA) for categorical variables and normally distributed continuous variables. Then, we set the models of generalized estimating equations (GEE) to evaluate the effects of changes in caregiving intensity on the level of depressive symptoms, which is flexible to analyse correlated data from the same subjects over time (43) and control the confounding variables that change over time, such as self-rated health status (44). Model

1 was specified to evaluate the effect of the caregiving transition on the dependent variable after taking into account a range of baseline covariates. To test Hypothesis 2 regarding whether the effect of transition of caregiving on depressive symptoms differed in gender and location groups, we divided subgroups in model 2, model 3, model 4 and model 5. Instead of cross-terms for care intensity with gender and urban/rural residence, we operated models by groups to better understand the internal characteristics of different samples.

4. Results

4.1. Descriptive statistics

Table 1 suggests descriptive information of the sample at baseline. According to the stability and change in grandchild care, only 33.44% of grandparents provided no care at either wave. Close to one-fifth of grandparents in Wave 2 continued to provide the same level of intergenerational care reported in Wave 1: 10.78% continued to provide high-intensity care, and 8.39% continued to provide low-intensity care in Wave 2. More than 20% of grandparents increased their level of grandparenting: 15.01% provided no care at Wave 1 and any care for grandchildren in Wave 2; 6.94% provided low-intensity care at Wave 1 and high-intensity care at Wave 2. More than 25% of grandparents decreased the intensity of intergenerational care: 16.84% cared for grandchildren at Wave 1 and ended up at Wave 2; 8.59% provided high-intensity care at Wave 1 and low-intensity care at Wave 2.

There were significantly differences among four groups. Rural grandmothers had the highest scores for depressive symptoms, and urban grandfathers scored the lowest. Rural grandparents had a higher proportion of noncaregivers than urban samples, while urban grandparents had a higher proportion of continuous low-intensity and decreased-intensity care. In total, urban grandfathers were the most educated, the least single, had the best self-assessed health status, had the least number of grandchildren, and had the highest level of individual household expenditure. However, rural grandmothers seemed to be the most disadvantaged in these socio-economic indicators.

4.2. Changes in caregiving intensity and depressive symptoms

The results of the longitudinal impact of grandparenting on depression are presented in Table 2. After controlling for sociodemographic characteristics and family information variables, stability and changes in grandparental childcare were associated with caregivers' depressive symptoms. Hypothesis 1 was supported. Grandparents who provided high-intensity care in Wave 1 and low-intensity care in Wave 2, who stopped childcare at Wave 2, and who offered low-intensity care in 2 waves were associated with a lower level of depression compared with those providing no childcare. Associations with other covariates were broadly similar to previous studies. Males, living in urban areas, higher-level education, being married or cohabiting, better self-assessed health status, older age, less children, and higher-level of household individual expenditure were associated with decreased depression.

The mental impact of change in grandparenting intensity revealed urban–rural and gender heterogeneity when respondents were divided into four groups. Hypothesis 2 was verified. Model 2 suggested that, compared with rural grandmothers who never participated in grandparenting, those who continued to provide high-intensity childcare were associated with an increased level of depression, and those who decreased the intensity of childcare were associated with a decreased level of depression. Model 3 showed that rural grandfathers who stopped childcare, and those who increased the intensity of childcare were associated with decreased depression when compared with noncaregivers. Model 4 suggested that urban grandmothers who provided continuous high-intensity or low-intensity childcare and those who increased the intensity of childcare were associated with decreased depression when compared with noncaregivers. Model 5 pointed out that the changes in childcare intensity were not significantly associated with urban grandfathers' depressive symptoms. Figure 1 more clearly displayed differences across groups.

4.3. Supplementary analysis

We examined the effects of 16 classification changes in grandparenting intensity based on distinguishment between four types of grandparent care: high-intensity care (i.e., over 40 h per week on average), moderate-intensity care (i.e., more than 10 h but less than 40 h per week on average), low-intensity care (i.e., under 10 h per week on average) and noncaregivers (13). The results (see Supplementary Table S3) indicated that, compared with noncaregivers, grandparents who provided continuous moderate-intensity caregiving, decreased the levels of grandparenting from high intensity to lower intensity, stopped caregiving in Wave 2 from moderate-intensity or low-intensity care in Wave 1, and started caregiving at a low intensity in Wave 2, were associated with decreased levels of depressive symptoms. The results were roughly the same but more detailed than the results above. In addition, providing continuous low-intensity childcare and starting caregiving at a high intensity in Wave 2 were associated with increased depressive symptoms among urban grandfathers. More details were given in Supplementary Table S3.

5. Discussion

As Chinese grandparents play an increasingly important role in intergenerational care, the impact of care activities on old caregivers' mental health has attracted scholars' attention. Caregiving can predict the change in depressive symptoms in both positive and negative ways (12), while there are few studies on how the changes in caregiving intensity affects depression symptoms. The study provided longitudinal evidence on the stability of grandparental care's effects, which further expanded the literature on how continuous grandparenting and its intersection of rural–urban and gender contexts impact mental health. Using the GEE model with longitudinal data from China, our findings suggested that the association between the changes in grandparenting intensity was not a simple one and varied in different groups. It appeared that stopping or decreasing the intensity of childcare was beneficial to grandparents' mental health. Residence and gender can exert different influences on caregivers' depression levels.

First, we confirmed that caregivers who continued caregiving could experience a lower level of depressive symptoms than their

TABLE 2 GEE regression of caregiving changes on grandparents' depression by subgroups.

	Model 1	Model 2	Model 3	Model 4	Model 5
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	2.770*** (0.034)	2.800*** (0.048)	2.575*** (0.064)	2.800*** (0.103)	2.264*** (0.156)
Changes of caregiving intensity (ref: no childcare at either wave)					
High-intensity childcare at both waves	−0.002 (0.024)	0.077* (0.035)	−0.043 (0.042)	−0.136* (0.068)	0.017 (0.074)
Low-intensity childcare at both waves	−0.048† (0.027)	−0.047 (0.042)	−0.034 (0.046)	−0.155* (0.072)	0.083 (0.075)
Starting childcare at Wave 2	−0.024 (0.021)	−0.042 (0.032)	−0.027 (0.034)	−0.038 (0.064)	0.068 (0.066)
Stopped childcare at Wave 2	−0.052** (0.020)	−0.026 (0.031)	−0.105** (0.032)	−0.065 (0.060)	0.042 (0.065)
High-intensity childcare → Low-intensity childcare	−0.067* (0.026)	−0.101* (0.042)	−0.046 (0.046)	−0.104 (0.067)	0.029 (0.079)
Low-intensity childcare → High-intensity childcare	−0.036 (0.028)	0.025 (0.042)	−0.093† (0.049)	−0.124† (0.076)	0.009 (0.086)
Gender (male)	−0.187*** (0.015)				
Location (city)	−0.095*** (0.017)				
Education (ref: illiterate)					
Primary school and below	−0.034* (0.017)	−0.027 (0.022)	−0.020 (0.036)	−0.025 (0.051)	−0.154 (0.101)
Middle school	−0.146*** (0.022)	−0.174*** (0.035)	−0.125** (0.040)	−0.136* (0.060)	−0.187† (0.103)
High school	−0.242*** (0.028)	−0.268*** (0.068)	−0.215*** (0.048)	−0.204** (0.069)	−0.322** (0.108)
College and above	−0.302*** (0.075)	0.019 (0.044)	−0.392* (0.199)	−0.119 (0.143)	−0.409** (0.138)
Marital status (married or cohabiting)	−0.170*** (0.021)	−0.214*** (0.029)	−0.167*** (0.042)	−0.131* (0.055)	0.021 (0.087)
Self-assessed health status (ref: poor)					
Fair	−0.456*** (0.014)	−0.431*** (0.020)	−0.467*** (0.024)	−0.508*** (0.039)	−0.502*** (0.051)
Good	−0.817*** (0.018)	−0.771*** (0.029)	−0.782*** (0.030)	−0.969*** (0.052)	−0.950*** (0.059)
Age in 2015 (ref: 45–60)					
60–70	−0.049*** (0.015)	−0.024 (0.022)	−0.020 (0.025)	−0.157*** (0.040)	−0.083† (0.046)
70–80	−0.107*** (0.022)	−0.088* (0.036)	−0.078* (0.036)	−0.222*** (0.067)	−0.129* (0.064)
Above 80	−0.199*** (0.050)	−0.121 (0.077)	−0.209** (0.073)	−0.050 (0.157)	−0.350* (0.152)
Living with their children	−0.018 (0.013)	−0.032 (0.021)	−0.017 (0.022)	−0.033 (0.038)	0.050 (0.042)
Number of grandchildren	0.004 (0.004)	0.007 (0.006)	0.001 (0.006)	0.022** (0.008)	−0.017 (0.014)
Number of children	0.023*** (0.006)	0.003 (0.010)	0.025* (0.010)	0.036* (0.017)	0.084*** (0.022)
Per capita household expenditure (ref: 1st quartile)					
2nd quartile	−0.069*** (0.016)	−0.048* (0.023)	−0.103*** (0.026)	−0.102† (0.054)	−0.032 (0.065)
3rd quartile	−0.103*** (0.016)	−0.073** (0.025)	−0.109*** (0.026)	−0.221*** (0.055)	−0.065 (0.062)
4th quartile	−0.106*** (0.019)	−0.069* (0.029)	−0.124*** (0.031)	−0.203*** (0.057)	−0.048 (0.065)
Number of observations	17,701	6,935	6,512	2,188	2066

†$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Model (1) to (5) uses samples of all samples, rural grandmothers, rural grandfathers, urban grandmothers and urban grandfathers in turn.

noncaregiving counterparts. This finding was similar to previous research (11, 14, 41, 45). And it is also in line with the Role Accumulation Theory which assumes that participating in caregiving activities may compensate grandparents for the loss of their former roles by injecting meaning into their lives (33). In particular, Chinese grandparents regard caring grandchildren as a productive role in Confucian filial piety culture (19). Based on research on the impacts of the continuity of caregiving, our study further provided strong evidence of the association between the changes in caregiving and depression among Chinese grandparents. The results emphasized the benefit of continuous moderate intensity care, decreased intensity of caregiving, and quitting intergenerational care. The advantage of moderate-intensity care has been pointed out before, while higher-intensity engagement could compromise health (12). Moreover, our findings were similar to the claim that the deterioration of grandparents' health may contribute to the cessation of intergenerational care while stopping grandparenting provided an opportunity for grandparents to recover (20). However, some researchers supported that grandparents with cessation of care had a higher risk of depressive symptoms over time, and the strong loss of self-efficacy, as well as the social and financial isolations, may account for the results (45, 46). It appeared that these articles used data from other countries in the early 20th century, while our findings emphasized that in recent China there seemed to be no extra mental benefit of long-term intensive care for grandparents. Against the background of modernity, Chinese young grandparents, on the one hand, maintain a certain degree of emotional need in intergenerational interaction and, on the other hand, gradually acquire the characteristics of independence (47). The youngest grandparents (i.e., from 45 to 69 years old) received

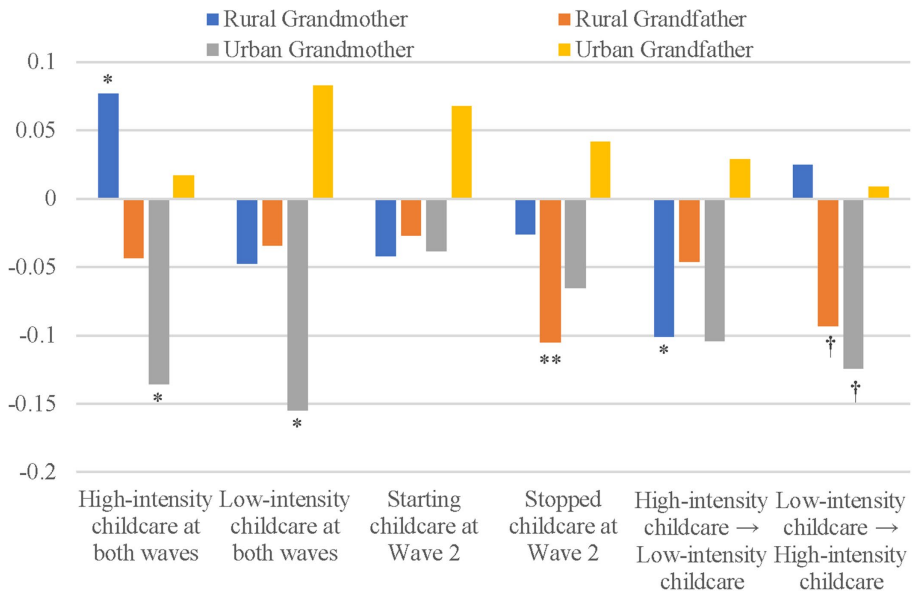

FIGURE 1
Effects of grandparenting intensity on health outcomes. The reference group of continuity and change in childcare is no childcare at either wave. Significance is based on the following values: †$p < 0.1$, *$p < 0.05$, **$p < 0.01$. Results are based on models control variables given in Table 2.

the most benefits of stopping and reducing the intensity of care, while the older grandparents did not (see Supplementary Table S4), which supported our interpretation to some extent. Furthermore, living with children was not found to be significantly associated with depressive symptoms in Chinese grandparents in the longitudinal study. It could be because older adults who did not live with children were more likely to receive financial assistance from children who could migrate and become better off, thereby preventing psychological damage for the old adults (36, 48). In addition, avoiding greater ambivalence toward family members also encourages parents to live apart from their children (49).

Second, our analyses of the conditional effects of care intensity changing by gender pointed out the compounding impact of gender norms and role theory on the links between caregiving and depressive symptoms. There were both similarities and heterogeneity in the impacts between rural grandfathers and rural grandmothers. On the one hand, reducing the intensity of care has a psychological bonus for rural grandmothers. It supported the Role Accumulation Theory that grandparents gained emotional fulfillment from the long-term family role, but the positive psychological effects became significant only if the role pressure was taken off, which suggested the applicability of Role Tension Theory to some extent. Similarly, rural grandfathers benefited from the cessation of caring. It showed the positive interactive effects of conforming to gender norms and taking on a caring role. On the other hand, increasing the intensity of caring for grandchildren could be beneficial for rural grandfathers, while rural grandmothers suffered from continuous high-intensity childcare. This finding was consistent with previous research showing that grandmothers may suffer more from the impact of role strain, such as being involved in high-intensity grandparenting (40). Caregiving activities seemed to be responsible and psychologically stressful for women, while they could be optional and joyful for men (31, 50). However, the impact of gender differences changed when it was estimated in urban society. Only urban grandmothers benefited from continuous caregiving, while urban grandfathers did not. It seems that the health benefit of providing sustained high-intensity care was especially noticeable among urban grandmothers. Caring was not associated with positive mental health outcomes for grandfathers in urban areas with strongly differentiated gender roles (21).

Third, findings on urban versus rural subgroups pointed out that the impacts of grandparenting on depressive symptoms were contingent on differential contexts. Compared with urban grandmothers acquired the psychological benefits from continuous caregiving at low intensity, increased intensity, and even high intensity, rural grandmothers only benefited from decreasing the intensity of grandparenting and suffered from continuous high-intensity care. These findings are consistent with previous research that urban grandparents tended to benefit more from intergenerational care than rural samples (31, 33). Because of less change in traditional norms and numerous left-behind children whose parents migrated for work in rural areas (51), compared with their urban peers, rural grandparents were more likely to take on intensive care and cope with psychological strains (2, 31). In addition, the lack of sufficient economic support may jeopardize the mental health of grandparents living in rural areas, while the availability of pensions and more financial resources helped to ease the burden of intensive caregiving for urban grandparents (33). Compared with rural grandfathers, involvement in grandparenting could not bring sufficient mental benefit that offset the negative impacts of deviation from gender norms for urban grandfathers, which revealed that there was no association between caring and depressive symptoms.

5.1. Limitations

There are some limitations in this study. First, specific contents of grandparenting activities, grandchild characteristics such as age or health, whether individuals care grandchildren collectively with their

spouses, and the reasons for changes in caregiving, which may be associated with caregivers' actual or perceived intensity of care activities but cannot be measured solely by caregiving time, were not available in the data. Thus, the impacts of intergenerational care could not be more accurate, and there may be some potential confounders that have not been controlled. Second, our study excluded participants who did not provide complete independent variables, dependent variables, and covariates, which may cause selection bias. Although there were no significant differences in depressive symptoms between the excluded samples and the included samples, the participants in our study had a higher likelihood of providing continuous caregiving and more favourable socioeconomic characteristics, which might be associated with a lower level of depression. This finding suggested that grandparents who were more capable of providing care might be oversampled, and favourable mental outcomes should be treated with caution. Third, although we used longitudinal data, these findings may not be a strict casual but only a causal inference under the social science paradigm, because intergenerational care and depressive symptoms were observed simultaneously.

6. Conclusion

By using longitudinal and nationally representative data from China, our study pointed out the effect of variation and persistence of caregiving intensity on depressive symptoms of grandparents. The results suggested that continuous low-intensity caregiving, decreased levels of involvement, and the cessation of caregiving were associated with fewer depressive symptoms for Chinese grandparents. In addition, the study found the detrimental effects of persistent high-intensity grandparenting and a beneficial effect of reduced-intensity care for rural grandmothers, while urban grandmothers took the advantages of continuous low-intensity care, increased level of involvement in caregiving and continuous high-intensity care. It also turned out that rural grandfathers who stopped caregiving or provided decreased-intensity care were more likely to experience fewer depressive symptoms. On the one hand, we could advocate for older adults to assist in caring grandchildren at a moderate intensity, which is conducive to active aging. On the other hand, with widespread participation in intergenerational caregiving, the potential risk of long-term and high-intensity caregiving on the mental health of older Chinese grandparents should be considered. Rural grandmothers, in particular, need much more family support and even community-based interventions to help provide supplementary care for left-behind children in order to alleviate persistent stress. More research using longitudinal data on the health impacts of continuous and varied caregiving is needed. Moreover, when it is considered that China is experiencing the historical situation of drastic modernization transformation, studies and any new policy related to them need to be placed in the context of nations, culture, and socioeconomic characteristics.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: the dataset is available from the CHARLS repository, http://charls.pku.edu.cn.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Review Board at Peking University. Ethics approval no. IRB00001052-11015. The patients/participants provided their written informed consent to participate in this study.

Author contributions

WX and YH designed the study. YH contributed to the collection of literature, data processing, and result analysis and drafted the manuscript. WX contributed to the review of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1217998/full#supplementary-material

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Education counteracts the genetic risk of Alzheimer's disease without an interaction effect

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Background: Alzheimer's disease (AD) is a major cause of disability and mortality in older adults. This study aimed to investigate the association of AD with education and genetic factors.

Methods: We conducted a prospective cohort study using data from the UK Biobank. Genetic risk was assessed using a polygenic risk score for AD. The educational level was categorized as either low, intermediate, or high. AD was defined using the International Classification of Diseases and Related Health Problems, 10th revision. Logistic regression models were used to investigate the independent and combined effects of genetic factors and educational levels on the risk of AD.

Results: We included 318,535 participants in this study (age: 56.53 ± 8.09 years; male: 44.81%). Compared with a low genetic risk, a high genetic risk was associated with a significantly greater risk of AD (OR = 7.09, 95% CI: 6.09–8.26). A high educational level was associated with a 30% lower risk of AD compared with a low educational level (OR = 0.70, 95% CI: 0.60–0.81). Combining genetic risk and education categories, individuals with a low genetic risk and high educational level had a more than 90% (OR = 0.09, 95% CI: 0.05–0.16) lower risk of AD compared to those with a high genetic risk and low educational level. There was no significant interaction between genetic risk and educational level regarding AD risk (p for interaction = 0.359).

Conclusion: Education counteracts the genetic risk of AD, without an interaction effect. Increasing education to reduce the incidence of AD is of same importance across individuals with different genetic risk.

KEYWORDS

education, genetic risk, Alzheimer's disease, dementia, polygenic risk score

1. Introduction

Dementia is a major cause of disability and death in older adults and imposes a significant economic burden (1–3). The World Health Organization estimated that approximately 50 million people worldwide had dementia in 2019, equating to an economic burden of 1.3 trillion US dollars (4). The global prevalence of dementia has been steadily increasing, and the number of people with dementia has been predicted to reach 130 million by 2050 (5). Alzheimer's disease (AD) accounts for approximately 70% of all cases of dementia worldwide (6). Given the scale

and impact of this disease, reducing its incidence is of paramount importance.

Previous reviews have identified a multitude of factors related to AD, including genetic, demographic, socio-behavioral, and biological factors (7–9). Genetic factors have been recognized as the primary cause of AD in humans (10). A series of twin studies showed that 60–80% of the risk of developing AD is attributable to genetic factors (11). Genome-wide association studies have identified gene polymorphisms associated with the development of AD (12, 13). Single nucleotide polymorphisms have provided quantitative measures of genetic susceptibility, and the polygenic risk score (PRS) has been used to quantify the genetic risk of AD by integrating information from sensitive genetic loci found in genome-wide association studies (14, 15).

A low educational level is recognized as a risk factor for the development of AD (16, 17). A systematic review and meta-analysis of factors associated with AD risk reported odds ratios (ORs) of 2.61 and 1.88 in prevalence and incidence studies, respectively, for low education versus high education (18). The mediating effect of intelligence on educational attainment and AD risk has been demonstrated by a Mendelian randomization study (19). Cognitive reserve refers to the total amount of cognitive resources that individuals are able to mobilize in the face of cognitive challenges. Evidence from a brain structural image analysis showed that education increased the cognitive reserve against AD by increasing regional cortical thickness in healthy controls; this effect also helped AD patients to cope better with the effects of brain atrophy (20).

New strategies for disease prevention have comprised the exploration of gene–environment interactions and the attenuation of genetic risk *via* health-promoting factors (21–23). Previous studies have investigated the interaction between the genetic factors of AD and environmental variables, such as diet, alcohol, smoking, and pollutants (24–27). A study has found education has the same effect on the risk of AD among individuals with APOEε4 gene or without (28). This study aims to explore whether the association between education and the risk of AD was the same at different levels of genetic risk (using PRS) for AD by analyzing data from a large-scale United Kingdom (UK) population cohort. Confirmation of this interaction would help to predict the risk of AD more accurately and inform the development of optimal AD prevention strategies.

2. Materials and methods

2.1. Study design and participants

This study used data from the UK Biobank, a prospective population-based cohort study. The UK Biobank recruited 502,528 adults (56.53 ± 8.09 years old) from the general population across 22 assessment centers in England, Scotland, and Wales between 2006 and 2010. Participants completed touchscreen and nurse-led questionnaires, underwent physical measurements, and provided biological samples (29). The exposures of interest in this study were genetic risks and educational levels. We included all participants who had complete data on the standard PRS for AD, age at completion of continuous full-time education, and covariates at baseline.

2.2. Genetic risk

To assess the cumulative genetic risk of AD, we used the PRS, which was developed based on external genome-wide association summary statistical AD data in the Genetic Epidemiology Research on Adult Health and Aging study (30). An individual-level polygenic score was defined as the sum of the number of risk alleles present at each single nucleotide polymorphism, weighted by the corresponding posterior effect sizes across all available single nucleotide polymorphisms (31). As the genetic risk of AD in a population is approximately normal, most people have an intermediate risk. We categorized the genetic risk for all included individuals into low (<20%), intermediate (20–80%), and high (>80%) risk categories; this classification system has been widely used in other studies (32, 33).

2.3. Assessment of education

We used the age at the completion of continuous full-time education to assess the degree of education. This information was collected using touchscreen and nurse-led questionnaires at baseline. Participants were asked the following question: "At what age did you complete your continuous full-time education?." The participants were categorized as having either a low (the age at the completion of continuous full-time education: <16 years), intermediate (the age at the completion of continuous full-time education: 16–18 years), or high (the age at the completion of continuous full-time education: >18 years) educational level.

2.4. Ascertainment of AD

AD was defined according to the International Classification of Diseases and Related Health Problems, 10th revision, which is the primary classification system used by the UK Biobank. We used code G30 from the "first occurrence" data field generated by the UK Biobank. This code was ascertained by combining primary care center, hospital inpatient, death register, and self-reported data. The date of diagnosis was set as the earliest date on which the AD code was recorded, regardless of the source used.

2.5. Covariates

Covariates were selected based on previous research and baseline availability (34–36). Demographic variables, including sex (male and female) and age at baseline (categorized as <45, 45–49, 50–54, 55–59, 60–64, 65–69, and ≥ 70 years), as well as health behaviors such as smoking status (current or non-current), alcohol intake (<3 times per week or ≥ 3 times per week), and moderate physical activity (0, 1–2, 3–5, and 6–7 times per week) were obtained *via* touchscreen and nurse-led questionnaires at baseline. These measures of health behaviors have been widely used in other studies (32, 36). Biological factors including body mass index (BMI) (<25, 25–30, and > 30),

Abbreviations: AD, Alzheimer's disease; BMI, body mass index; CI, confidence interval; OR, odds ratio; PRS, polygenic risk score; UK, United Kingdom.

diabetes, and hypertension were also assessed, as previous studies have reported that obesity, diabetes, and hypertension are risk factors for AD (36). BMI was calculated by dividing self-reported weight (kg) by height (m^2) at baseline. Diabetes and hypertension were determined via medical records.

2.6. Statistical analysis

Logistic regression was used to investigate the association of AD with genetic risk, education, and combined genetic risk and education categories. ORs was used to show the relative strength of the risk of AD among different populations after adjusting covariates. To explore the influence of genetic risk and education on AD, these two variables were mutually adjusted. We examined the effects of education on AD development in populations with varying levels of genetic risk. To account for the potential impact of covariates on the association of AD with genetic risk and education, model 1 was adjusted for sex and age at baseline; model 2 was additionally adjusted for smoking status, alcohol intake, and physical activity; and model 3 was further adjusted for BMI, diabetes, and hypertension. Combined genetic risk and education categories were included as variables in the analysis. An interaction term was included in the regression model to test for statistical interactions between genetic risk and education in relation to AD. The effect of education on AD was also analyzed by stratifying for genetic risk. Bonferroni correction was made to reduce the probability of false positives.

2.7. Sensitivity analysis

We conducted two types of sensitivity analyses to evaluate the robustness of our findings. The first analysis involved re-categorizing PRS into low (<30%), intermediate (30–70%), and high (>70%) risk categories for all included individuals. The second sensitivity analysis explored potential differences in the risk of AD between males and females.

The significance level was set at $\alpha = 0.05$, and two-sided p-values less than 0.05 were considered statistically significant. All analyses were performed using SPSS.22 statistical software and R.4.1.2.

3. Results

3.1. Participants in the study

A total of 502,386 individuals were assessed at the baseline. After excluding participants without data pertaining to genetic factors ($n = 16{,}237$), educational level ($n = 165{,}186$), BMI ($n = 3{,}105$), health behaviors ($n = 12{,}898$), or diabetes and hypertension status ($n = 13{,}823$), a total of 318,535 participants were finally included in the study. During the study, 2,483 persons were diagnosed with AD. The participants' characteristics are shown in Table 1.

Figure 1 shows the percentages of participants with different levels of genetic risk and education: 31.2, 55.72, and 13.08% had low, intermediate, and high educational levels, respectively. Approximately one-third of participants had an intermediate genetic risk and low educational level, while 2.54% had a low genetic risk and high educational level. Across all levels of genetic risk, the educational level was most frequently classified as intermediate and least frequently classified as high.

3.2. The impact of genetic risk on AD

Table 2 presents the proportions and ORs for AD across different levels of genetic risk and education. The lifetime prevalence rates of AD were 0.30, 0.53, and 2.02% at low, intermediate, and high levels of genetic risk, respectively. In model 1 (which was adjusted for sex, age, and education), the ORs of AD were 1.76 (95% CI: 1.51–2.06) and 7.08 (95% confidence interval [CI]: 6.07–8.25) for intermediate and high genetic risk categories, respectively, versus low genetic risk. These results remained unchanged following additional adjustments for behavioral factors in model 2 and for both behavioral and biological factors in model 3. Similar results were observed in the sensitivity analyses for males (Supplementary Table S1), females (Supplementary Table S2), and different categories of genetic risk (Supplementary Table S3). These findings indicated that the genetic risk for AD was statistically independent of other factors.

3.3. The impact of education on AD

The proportion and risk of AD decreased monotonically across the education categories. As shown in Table 2, a higher educational level was associated with a lower proportion and risk of AD. In model 1 (which was adjusted for sex, age, and genetic risk), ORs were 0.78 and 0.70 for the intermediate and high education groups, respectively, versus the low education group. Similar results were observed following additional adjustments for behavioral factors in model 2 and both behavioral and biological factors in model 3. These results were also essentially unchanged following sensitivity analyses for males (Supplementary Table S1), females (Supplementary Table S2), and different categories of genetic risk (Supplementary Table S3), thus indicating that education was independently associated with AD.

3.4. The combined impact of genetic risk and education on AD

Analyses of combined genetic risk and education categories revealed an overall monotonic association between lower genetic risk and higher education (Figure 2). Participants with a low genetic risk and high educational level had a lower risk of AD compared to those with a high genetic risk and low educational level (OR = 0.09, 95% CI: 0.06–0.15), after adjustment for all covariates. No significant interaction was observed between genetic risk and education in relation to AD (p for interaction = 0.359), indicating that the association between AD and education did not vary substantially across different levels of genetic risk. The details of the combined effects of genetic risk and education are shown in Supplementary Table S4. The sensitivity analyses (male: Supplementary Figure S1 and Supplementary Table S5; female: Supplementary Figure S2 and Supplementary Table S6; different categories of genetic risk: Supplementary Table S7 and Supplementary Figure S3) yielded similar results.

TABLE 1 Characteristics of participants included.

Characteristics	All	AD	Non-AD	*p* value
Age at baseline				<0.001
<45 years	28,070 (8.81)	6 (0.02)	28,064 (99.98)	
45 ~ 49 years	38,057 (11.95)	18 (0.05)	38,039 (99.95)	
50 ~ 54 years	44,984 (14.12)	50 (0.11)	44,934 (99.89)	
55 ~ 59 years	55,317 (17.37)	158 (0.29)	55,159 (99.71)	
60 ~ 64 years	82,443 (25.88)	699 (0.85)	81,744 (99.15)	
65 ~ 69 years	67,900 (21.32)	1,479 (2.18)	66,421 (97.82)	
≥70 years	1764 (0.55)	73 (5.27)	1,671 (94.73)	
Sex				0.087
Male	142,744(44.81)	1,155 (0.81)	141,589 (99.19)	
Female	175,791 (55.19)	1,328 (0.76)	174,463 (99.24)	
Genetic risk				<0.001
Low	63,708 (20.00)	191 (0.30)	63,517 (99.70)	
Intermediate	191,120 (60.00)	1,004 (0.53)	190,116 (99.47)	
High	63,707 (20.00)	1,288 (2.02)	62,419 (97.98)	
Education				<0.001
Low	99,375 (31.20)	1,290 (1.30)	98,085 (98.70)	
Intermediate	177,484 (55.72)	980 (0.55)	176,504 (99.45)	
High	41,676 (13.08)	213 (0.51)	41,463 (99.49)	
Smoking status				
current	37,956 (11.92)	227 (0.60)	37,729 (99.40)	
non-current	280,579 (88.08)	2,256 (0.80)	278,323 (99.20)	
Alcohol intake				<0.001
< 3 times/week	251,197 (78.86)	1763 (0.70)	249,434 (99.30)	
≥3 times/week	67,338 (21.14)	720(1.07)	66,618 (98.93)	
Moderate physical activity				<0.001
0 time/week	43,271 (13.58)	317 (0.73)	42,954 (99.27)	
1 ~ 2 times/week	66,617 (20.91)	433 (0.65)	66,184 (99.35)	
3 ~ 5 times/week	128,242 (40.26)	949 (0.74)	127,293 (99.26)	
6 ~ 7 times/week	80,405 (25.24)	784 (0.98)	79,621 (99.02)	
BMI				0.530
<25	94,412 (29.64)	754 (0.80)	94,412 (99.2)	
25 ~ 30	138,032 (43.33)	1,081 (0.78)	138,032 (99.22)	
>30	86,091 (27.03)	648 (0.75)	86,091 (99.25)	
Diabetes				<0.001
Yes	17,206 (5.40)	290 (1.71)	16,916 (98.29)	
No	301,329 (94.60)	2,193 (0.73)	299,136 (99.27)	
Hypertension				<0.001
Yes	86,500 (27.16)	895 (1.03)	85,605 (98.97)	
No	232,035 (72.84)	1,588 (0.68)	230,447 (99.32)	

3.5. The impact of education on AD across different levels of genetic risk

The effect of education on AD following stratification by genetic risk and adjustment for all covariates is shown in Table 3. Compared to a low educational level, intermediate and high educational levels were associated with 21% (OR = 0.79, 95% CI: 0.58–1.07) and 35% (OR = 0.65, 95% CI: 0.38–1.08) lower risks for AD, respectively, among participants with a low genetic risk. Among participants with an intermediate genetic risk, an intermediate educational level was associated with a risk reduction of 24% (OR = 0.76, 95% CI: 0.66–0.87), while a high educational level was associated with a risk

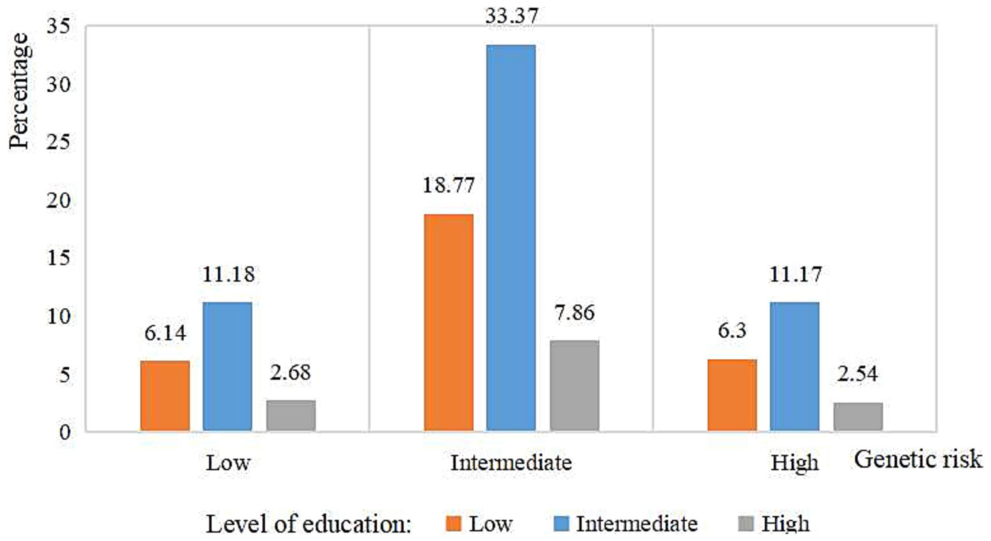


FIGURE 1
Percentage of level of education according to genetic risk categories risk of AD.

TABLE 2 Risk of AD according to genetic risk and education categories.

	AD proportion	Model 1	Model 2	Model 3
Genetic risk				
Low	0.30% (191/63708)	1 (Ref)	1 (Ref)	1 (Ref)
Intermediate	0.53% (1,004/191120)	1.76 (1.51, 2.06)	1.77 (1.51, 2.06)	1.76 (1.51, 2.06)
High	2.02% (1,288/63707)	7.08 (6.07, 8.25)	7.10 (6.09, 8.27)	7.09 (6.09, 8.26)
Education				
Low	1.30% (1,290/238504)	1 (Ref)	1 (Ref)	1 (Ref)
Intermediate	0.55% (980/68019)	0.78 (0.71, 0.85)	0.80 (0.73, 0.87)	0.79 (0.72, 0.86)
High	0.51% (213/12012)	0.70 (0.60, 0.81)	0.71 (0.61, 0.83)	0.70 (0.60, 0.81)

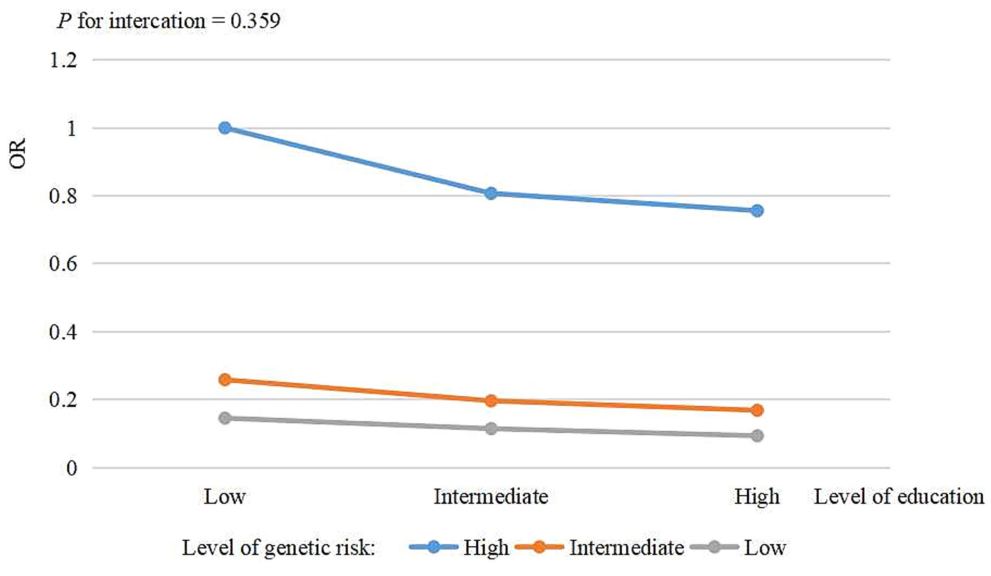
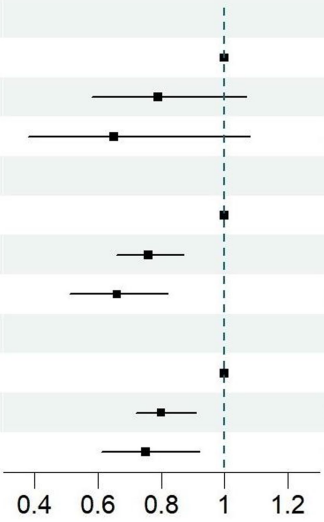


FIGURE 2
The risk of combined genetic risk and education for AD.

TABLE 3 The effect of education on AD stratified by genetic risk.

Subgroup	AD/Total	OR (95% CI)
Low genetic risk		
Low education	99/19560	1 (Ref.)
Intermediate education	76/35610	0.79 (0.58~1.07)
High education	16/8538	0.65 (0.38~1.08)
Intermediate genetic risk		
Low education	191/63708	1 (Ref.)
Intermediate education	534/59786	0.76 (0.66~0.87)
High education	387/106287	0.66 (0.51~0.82)
High genetic risk		
Low education	657/20029	1 (Ref.)
Intermediate education	517/35587	0.80 (0.72~0.91)
High education	114/8091	0.75 (0.61~0.92)



reduction of 34% (OR = 0.66, 95% CI: 0.51–0.82). Among participants with a high genetic risk, intermediate and high educational levels were associated with 20% (OR = 0.80, 95% CI: 0.72–0.91) and 25% (OR = 0.75, 95% CI: 0.61–0.92) reductions in risk for AD, respectively. These results were not significantly altered in the sensitivity analyses for males (Supplementary Figure S4), females (Supplementary Figure S5), and the different categories of genetic risk (Supplementary Figure S6).

4. Discussion

The 1970s and 1980s saw major changes in the British educational system. Universal access to general and vocational education increased significantly, with a 50% high school enrollment rate (37). Most of the participants in this study completed their education during this period. Individuals in the UK typically complete high school at 16–18 years of age (38). They then have the option of pursuing higher education or entering the workforce. In our study, the distribution of educational levels among the participants reflected the overall trend in the UK at that time.

In this prospective, population-based, large-scale study, we found that genetic risk and education were associated with the risk of AD. This finding is consistent with previous studies (16, 17, 28). After adjusting for education, individuals with a high genetic risk were six times more likely to develop AD than those with a low genetic risk. This suggests that identifying individuals at high genetic risk could facilitate a more precise targeting of individuals for AD prevention. After adjusting for genetic risk, the risk of AD decreased by 30% among participants with a high educational level compared to those with a low educational level. The risk decreased by 21% even among participants with an intermediate level of education. No significant interaction was observed between genetic risk and educational level. A beneficial effect of higher education on AD was found across all levels of genetic risk. This suggests that the incidence of AD could be reduced at a population-wide level through higher education, which was consistent with the research results that used the presence of the APOEε4 gene as a genetic risk grouping (28).

To the best of our knowledge, this is the first study to investigate the association between AD and combinations of different levels of education and genetic risk. Previous studies have shown that education and genetic risk are associated with other diseases, such as obesity and diabetes (39, 40). By analyzing different combinations of genetic risk and education categories, it was found that the risk of AD was decreased by more than 90% in people with a low genetic risk and high educational level, relative to those with a high genetic risk and low educational level. Combining genetic risk and education may facilitate a more precise prediction of AD. Therefore, the adoption of other measures, such as healthy lifestyles, for reducing the risk of AD is particularly important for individuals with a high genetic risk and low educational level (32).

The findings of our study could be explained previous studies (41–45). Primary education plays a crucial role in equipping individuals with fundamental hygiene knowledge and fostering a healthy lifestyle (41). Secondary education, on the other hand, enhances individuals' comprehension abilities and significantly improves health literacy (42). Furthermore, higher education empowers individuals to access more resources for personal development, thereby further augmenting their capacity to uphold good health (19). Some researchers believe that dementia occurs due to a decline in the cognitive reserve below a certain threshold (43). A higher level of education provides individuals with an increased cognitive reserve, thereby lowering the risk of dementia. Other studies have also suggested that the association between educational attainment and the reduced risk of AD is driven by intelligence. Individuals with higher education develop more cognitive reserve, so they are able to mobilize more resource to prevent AD (19, 45). In addition, educational attainment shapes reactions to genetic risk for AD (43). Individuals with a higher educational level tend to exhibit more health-promoting behaviors, while they have greater material, psychological, and social resources for maintain good health (46).

4.1. Limitations

Although this study was based on a large-scale survey, several limitations are acknowledged. First, education was evaluated based on the age at which participants completed continuous full-time education, which may not reflect the exact amount of time spent on education. However, it is likely to reflect a significant level of educational attainment (38). Due to a lack of data on part-time education, this study did not consider the impact of this type of education on AD occurrence. Second, the method used to identify AD cases may have been inadequate. Nonetheless, the use of primary care, hospital inpatient, death register, and self-reported data included more than 82.5% of the relevant records (47). Third, some researchers hold the view that individuals with high education still get AD, however, the symptoms of AD are often staved off for a longer period of time (48). This study did not consider the differences in this delayed effect among different genetic risk groups. Fourth, the relationship between education and AD risk is complicated. Mediating variables of this relationship were not explored in this study. Fifth, this study was restricted to individuals in the UK aged 37–73 years at baseline. Therefore, caution should be exercised when generalizing the findings in this study to other populations.

4.2. Implications

The results of this study suggest that higher education is associated with a decreased risk of AD, regardless of genetic risk. Compared to individuals with lower levels of education, even those who have not received higher education but completed secondary education (approximately at ages 16–18) exhibit a significant reduced risk of developing AD. Furthermore, this effect is consistent across different levels of genetic risk. These findings have important implications for population-wide public health practices aimed at preventing AD. Fostering a conducive educational environment and offering abundant educational opportunities (such as free secondary education) is crucial for governments and societies. Additionally, individuals actively pursue higher education also play a significant role in the prevention of AD within the population (49). This study explored the correlation between AD and educational levels, which were based on the age at which continuous full-time education was completed. Future studies should also consider the influence of part-time education on the risk of developing AD. The effect of education on the risk of AD in different genetic risk groups should also be explored from the perspective of higher education delaying the onset of AD.

4.3. Conclusion

The results of this study indicate that genetic risk and education are independently associated with the risk of AD. Higher educational attainment may decrease the risk of AD, regardless of an individual's genetic risk. Hence, it is equally crucial for individuals with varying genetic risk to prioritize augmenting educational attainment in order to reduce the risk of AD. Governments and societies should foster a conducive educational environment, while individuals should actively seize educational resources to maximize their impact.

Data availability statement

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

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

XL collected the data, processed statistical data, and drafted the manuscript. YuZ, CZ, YiZ, and RL contributed to processed statistical data, and drafted the manuscript. SX contributed to the study design, manuscript edits, and supervised the project. All co-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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1178017/full#supplementary-material

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Older adults' perspectives towards optimizing lifestyle behaviors and strategies to support healthy brain ageing during COVID-19 restrictions

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Introduction: It is unknown how the impact of COVID-19 restrictions has affected brain healthy behaviors that contribute to dementia risk reduction in older adults. Our aim was to explore perspectives of older adults on lifestyle behaviors that support positive brain health and dementia risk reduction during and following COVID-19 restrictions.

Methods: Community-dwelling older Australians ($N = 159$) during June to October 2021 (the second wave of COVID-19 restrictions) who had taken part in a pre-post dementia risk reduction intervention program were invited to discuss the impact of COVID-19 on their lifestyle behaviors. Semi-structured interviews explored individual's adaptability to pandemic restrictions, intended behavior changes following restrictions easing, and feedback on the effectiveness of ongoing intervention programs for sustaining brain health. Thematic data analysis was performed using a deductive approach.

Results: Participants had an average age of 73.1 years (SD = 5.6; range: 65–90), majority were female (74.7%), lived in a major city (82.2%) and mean 9.5 years (SD = 1.7) of education. Older adults' views about lifestyle prevention strategies during the pandemic were both positive (e.g., more spare time and adaptive leisure activities) and negative (e.g., social isolation, lack of motivation, adverse emotions). Participants highlighted a continuous conscious effort to adapt certain brain healthy behaviors despite the persistence of adverse impacts of COVID-19 restrictions. Participants also expressed the intention and desire to revert to their previous lifestyle before the COVID-19 pandemic or a sense of the 'new normal'.

Conclusion: This formative research will inform future interventions targeting dementia risk reduction to consider the immediate and lasting effects of COVID-19 restrictions on older adult's lifestyle behavior.

KEYWORDS

COVID-19 impact, dementia, risk reduction, lifestyle behaviors, older adults, brain health

1. Introduction

Globally, there is increasing evidence that modifying risk factors can potentially reduce the risk of developing dementia and support brain health in later life (1–6), with increasing awareness that dementia prevention should be targeted systematically (6–9). Several lifestyle interventions targeting multiple dementia risk factors have thus been developed and implemented (10–13). Such interventions typically focus on encouraging lifestyle changes. For example, two large scale interventions (i.e., FINGER trial (5) and Maintain Your Brain (14)) provided conservative evidence of success in improving cognitive functioning and decreasing modifiable dementia risk (2, 15, 16); and an intervention for self-management led to improvements in cardiovascular risk profiles (e.g., HATICE trial (4)). Other interventions have had no effect on sustaining cognition over time (e.g., PreDIVA (17), MAPT (17)) and there is yet to be a clinical trial that demonstrates a reduction in dementia incidence as a result of individual-level multidomain lifestyle interventions (18).

In addition to these multidomain randomized controlled trials, public health initiatives aim to educate, raise awareness and provide the environmental opportunity and conditions for individuals to make lifestyle changes are also being rolled out (19, 20). For instance, a 10 month public health campaign in Netherlands, which utilized media and community participation, examined the campaign's ability to raise awareness of modifiable dementia risk reduction and increase motivation for behavior change (19). Despite not reaching a population-level increase in awareness of dementia risk reduction, the study demonstrated that exposure to the campaign led to a greater awareness and motivation for behavior change. However, effective population-level prevention requires both individual motivation for behavior change, along with public health action supported by widespread societal and policy change which poses additional systemic challenges (6, 21, 22).

Despite the promise of developing and adopting public health campaigns to target behavior change for dementia risk reduction, these findings are from a substantially different context to the coronavirus disease 2019 (COVID-19) pandemic climate (23, 24). The COVID-19 pandemic and its associated restrictions and lockdowns have significantly affected the daily lives of all individuals, but particularly older adults (25–27). The multiple waves of COVID-19 restrictions on leisure and gatherings have reduced older adults' rate of physical activity and social engagement (28), further exacerbating the severity of dementia risk factors (e.g., limiting physical activity, enforcing social isolation), and creating associated cascading effects on health and wellbeing (e.g., poor dietary choices, sleep problems, perceived stress) (29).

Only a few studies have explored how lifestyle behaviors may have altered during the pandemic. Bartlett and colleagues (30) demonstrated no detrimental effects of restrictions on the lifestyle behaviors of older adults before and during COVID-19 restrictions. However, these findings may be attributed to the 4-week dementia risk reduction program Preventing Dementia Massive Open Online Course (PD-MOOC) that the sample were engaged in at the time. Compared to the personalized, planning and action-oriented focus of BRAIN BOOTCAMP (31), the PD-MOOC is primarily educational, aiming to build knowledge of self-management of modifiable risk factors, thus our study will add to the evidence surrounding the protective nature of multidomain lifestyle programs.

Specific to brain health, Waterink and colleagues (32) found that 74% of participants reported at least one adverse lifestyle change, however, 60% of participants also reported at least one positive change including increased exercise, healthier food consumption and reduced alcohol consumption. These behaviors also differed based on sociodemographic factors such as age, gender, living circumstances, and income. Younger older adults, females, individuals living alone and in urban areas and individuals with an unsatisfactory income, reported more negative impacts on their lifestyle in a Dutch sample (32); whilst females, unemployed, retired and those reporting better adherence to restrictions, reported diminished physical activity in an Italian sample (33). Although long-term impacts of COVID-19 on lifestyle are unknown, research highlights the need to consider the sustained impacts of COVID-19 restrictions on vulnerable populations, including physical, financial and social recovery after COVID-19 restrictions and the fundamental changes in the way people think/behave and institutions operate. This is important within public health interventions or campaigns when designing and implementing methods to increase awareness, generate reductions in dementia risk, and encouraging older adults to remain brain healthy even in new and potentially adverse circumstances.

Understanding the impact of the COVID-19 pandemic on behavior change will be essential to informing the development of an effective dementia prevention intervention that targets the specific needs of older adults and is context-specific. Therefore, the aim of this qualitative study was to explore how the COVID-19 pandemic affected older adults' habits and to provide strategies and recommendations for future developments that target dementia prevention in a post-pandemic era.

2. Methods

2.1. Participants

Participants were older adults residing in New South Wales (NSW), Australia, who had recently partaken in the BRAIN BOOTCAMP pre-post prospective intervention program for brain health, involving a lifestyle behavioral modification program to improve dementia literacy and reduce dementia risk among older adults. Further details on the program have been published elsewhere (31). Older adults were recruited using standardized advertising methods including flyer dissemination (e.g., in primary care clinics, memory clinics, local community newsletters, and radio) in NSW, Australia. The opportunity to participate was also provided to disadvantaged or vulnerable communities (e.g., low socioeconomic status, ethnic minorities) through larger organizations who keep a registry of pre-existing members willing to participate in such research. Older adults were eligible if they were 65 years of age or more and were community-dwelling. They were required to be English-speaking and without significant self-reported depressive episodes, existing diagnosis of dementia, inability or refusal to provide informed consent, or current registration in another lifestyle modification intervention.

2.2. Procedure

Originally, 853 participants were recruited for the intervention program between January 2021 and March 2021. All participants who

completed the intervention program were invited to take part in a semi-structured telephone interview.

Telephone interviews were completed during the second COVID-19 restrictions in NSW, Australia, between 26 June to 11 October 2021 (15 weeks of COVID-19 restrictions in total). This was during the height of the pandemic in Australia and restrictions included lockdowns with participants unable to leave their homes except for essential work and exercise within 5 km of their local government area (34). Residents were not allowed to visit family or friends during this period and were only able to see those in their households. The majority of retail shops were closed except for grocery stores or retail outlets that had 'click and collect' available. Residents in NSW were unable to travel out of Greater Sydney and all state borders within Australia were closed. Schools were also closed during this time, with children requiring home-schooling. Community sport and other face-to-face recreational activities were put on hold for this period.

Researchers conducted semi-structured interviews as part of a broader mixed-method longitudinal study (31). Both researchers (JS, LD) were present for 85.7% of interviews. The purposive sampling considered the variability of participants in terms of age, current brain risk score (high and low modifiable dementia risk), gender (male and female), locality (major city or other) education (primary, secondary, tertiary), country of birth, primary language (English or other), and socioeconomic status (high and low). A semi-structured interview guide using a conversational style was developed by the research team and consisted of 4 key open-ended questions to guide the interview (see Supplementary material). The interviews began with a question regarding the impact of COVID-19 on the participant's lifestyle behaviors, followed by questions surrounding their capability to adapt to the restrictions imposed by the pandemic, intended behavioral adaptations following the anticipated lifting of restrictions, and any suggested improvements or feedback future intervention programs for their ongoing brain health.

2.3. Qualitative data analysis

All interviews were audio recorded and transcribed verbatim for content analysis using combined assistive technology (e.g., Zoom, OtterAI). Transcripts were checked for accuracy by the moderator (JS) and research team (LD). Grounded theory (35) and the self-regulatory (SRM) framework (36) were used to evaluate the transcripts. A randomly selected 20% of transcripts were read independently by two researchers (JS, CB) and an initial framework was developed. Thematic data analysis was performed using an deductive approach by two researchers for the remainder of the transcripts (JS, CB). Although specific key research questions were answered and guided the analysis, open coding was applied with no pre-set codes; rather codes were developed from interpretation of the data and modified throughout the analysis as required. The general process of qualitative data extraction included familiarity with the data, initial coding of data, allowing key meaningful themes and sub-themes relevant to the study objectives to be extracted from the data. These were then reviewed, re-considered with respect to coding and study objectives and then adapted as necessary to form emergent themes. After internal discussions between JS and CB, the framework was further refined and applied to the remainder of the transcripts. NVivo V20 was used to manage the transcripts and assist with analysis.

3. Results

3.1. Characteristics of study sample

A total of 165 eligible urban-dwelling, older adults received an invitation to participate in the telephone interviews for the present study, of which 159 (96.4%) accepted the invitation and completed a semi-structured telephone interview. Demographics of the included study participants are listed in Table 1.

3.2. Themes

Through deductive thematic coding and data analysis, emergent themes were grouped into four main themes and fifteen subthemes. The four main themes were: (1) Lifestyle impacts of the COVID-19 pandemic and corresponding restrictions in Australia; (2) Lifestyle adaptations during COVID-19 restrictions for continued brain health; (3) Anticipated brain-healthy lifestyle behaviors following COVID-19 restrictions; and (4) Consideration of future brain health initiatives to minimize ongoing COVID-19 impacts on lifestyle behaviors. Each theme is discussed in more detail below, with specific examples from

TABLE 1 Sociodemographic characteristics of participants (*N* = 159).

Characteristic	*N* (%)
Gender	
Female	118 (74.7)
Male	40 (25.3)
Age (mean [SD], range)	73.1 [5.6], 65–90
65–69	50 (31.7)
70–79	87 (55.1)
80+	21 (13.3)
Country of birth	
English-speaking country	141 (89.2)
Non-English speaking country	17 (10.8)
Education in years (mean, [SD], range)	9.5 [1.7], 0–30
Socioeconomic status (quintile)	
1 (lowest)	12 (7.6)
2	21 (13.4)
3	24 (15.3)
4	14 (8.9)
5 (highest)	86 (54.8)
Locality	
Metropolitan	129 (82.2)
Regional	28 (17.8)
Modifiable dementia risk (LIBRA index) (mean [SD], range)	−3.1 [2.5], −5.9–3.1

LIBRA, LIfestyle for BRAin Health index; SD, standard deviation.

each sub-theme and corresponding direct quotes from study participants as evidence of the deductive approach adopted for analysis. Furthermore, a diagrammatic representation of emerging themes and sub-themes is visually displayed as a theoretical framework in Figure 1.

3.2.1. Theme 1: lifestyle impacts of the COVID-19 pandemic and corresponding restrictions in Australia

Participants provided a range of descriptors relating to impacts of the COVID-19 pandemic and its associated restrictions on their lifestyle. Such descriptors included concerns for the future, feelings of frustration and uncertainty, negative impacts of lockdown, positives of the experience, reflections on life and acceptance of the situation. Some of these were positive or neutral, while others were entirely negative, or a combination of both positive and negative. Participants who described concerns for the future primarily discussed feelings of worry, skepticism and sadness. They expressed worries and fears about what the future would look like for the next generations and considered if the present situation would end up becoming permanent as a 'new normal'.

> *"I would wake up and feel really sad and I would say what kind of a world are my grandchildren coming into? And this is my worry for the future of my children and my grandchildren." (P24).*

The restrictions imposed by the COVID-19 pandemic also created feelings of frustration and uncertainty for many participants. Many expressed becoming increasingly lazy as a result, which for some was an unexpected feeling, and was possibly brought on from a lack of motivation.

> *"And I find I sit around a lot more which is not quite so good. Although I am a competitive sports person, my default position is laziness. And lockdown invites laziness." (P30).*

Many respondents reported negative impacts on lifestyle factors that support brain health. Some felt that they had less motivation to exercise from home and stated that the environmental impact of not being able to access exercise facilities reduced the ability to stay physically healthy (e.g., gyms, fitness classes).

> *"It has obviously made it impossible to continue the activities I felt were keeping me physically healthy, like Pilates and going to the gym." (P415).*

Others noted that they had put off necessary health tests, or developed bad habits around their diet, such as an increase in alcohol consumption.

> *"I was due for blood tests and a bone density scans, just physical health issues. And I have been putting them off and putting them off because I did not want to go into that environment." (P470).*

> *"We had started to drink more." (P114).*

Furthermore, environmental restrictions substantively influenced social lifestyles, with respondents missing the social aspect more than any other element, describing it as a critical part of their lives. Although most were able to maintain regular contact with family and friends through the telephone and other teleconferencing platforms such as Zoom, some individuals were not able to socialise and described it as a huge loss. Others also expressed their dislike of the

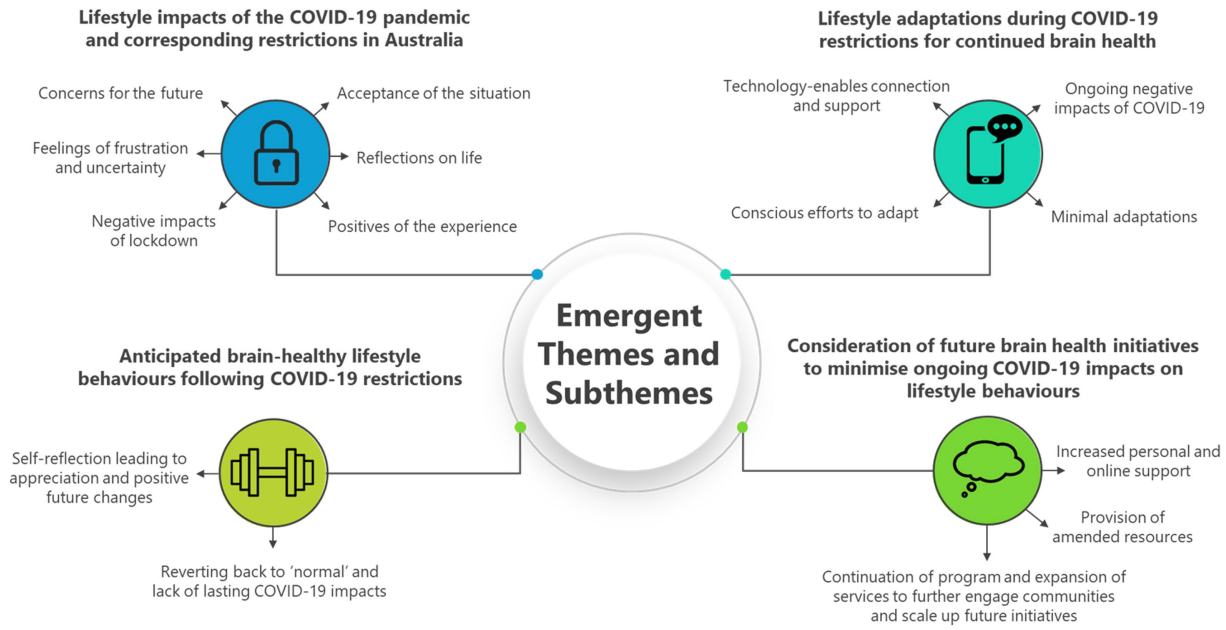

FIGURE 1
Thematic framework of emerging themes and sub-themes following analysis.

reliance on technologies such as Zoom as it did not replace real life face-to-face interaction:

> *"A lot of things have gone on Zoom, and I find Zoom very unsatisfactory as it feels like you are not talking to real people, like you are looking at an album or postage stamps." (P615).*

However, not all participants felt the COVID-19 restrictions were entirely negative. Many described positive impacts of the experience, such as how the allowance of individual time due to restrictions permitted a conscious effort to increase their mental stimulation and opportunities for familial socialization. They described feelings of togetherness and gratitude for the individual situation they were in. Some found the imposed lockdowns useful since COVID-19 could be a good excuse to cancel social plans. Others also used this additional time at home to achieve personal goals and develop new skills.

> *"I mean it's changed my lifestyle but not in a bad way. I'm probably walking more in COVID and sometimes I walk for an hour and a half and do 2000 steps which I did not have time to do before COVID." (P583).*

3.2.2. Theme 2: lifestyle adaptations during COVID-19 restrictions for continued brain health

Participants discussed a variety of adaptations to adapt to the COVID-19 situation in order to continue to care for their brain health. Many described conscious efforts to adjust to the situation, such as through new use of technologies to enable ongoing social connection and personal support.

> *"I just wanna be as healthy and fit as I can be in any circumstances." (P224).*

A large proportion of participants described efforts to adapt around increasing or continuing exercise, particularly around walking, which for some has also meant they can have some social connection at the same time.

> *"You can only meet up with one person at a time, and fortunately I have a friend I walk with every day." (P456).*

Other forms of mental stimulation frequently described by participants included word puzzles and Sudoku, reading, writing, planning and ongoing study. Others have also been exposed to home schooling or trying new or more challenging hobbies.

> *"I love cryptic crosswords. I do cricket crosswords. I do code breakers. I do a Master of Research." (P35).*

In response to COVID-19 restrictions, respondents stated that they primarily adapted their lifestyle by utilizing more technology and practicing conscious motivational efforts when it came to maintaining or increasing healthy brain activity. The majority of respondents noted that through the use of technology, they were able to keep some social connections going through restrictions with family and friends via Skype, Zoom, emailing and more.

> *"I'm socially active with friends and different groups, either by email or Facebook or phone calls." (P40).*

Others stated that the restrictions had influenced them to use technology to support everyday activities such as online shopping.

> *"For the first time ever, buying food online rather than go to the local store." (P9).*

Conscious motivational efforts were a primary adaptive response to the COVID-19 restrictions, particularly with mental stimulation which ranged from puzzles, crosswords, painting, knitting, reading and online games.

> *"I am doing a bit more in the sphere of crosswords and games, and online problem-solving as well." (P415).*

However, many participants continued to describe the negative impacts of COVID-19 and associated restrictions on their ability to adapt. Some of these reasons were ongoing reductions in motivation to exercise, not wanting to go outside of their comfort zone to try new things, regressing behaviors and simply not adapting well to the drastic changes imposed upon them. Others made little to no conscious effort to adapt their lifestyle behaviors to maintain optimal brain health.

> *"I've been exercising a bit less. The classes in the gyms and things have closed down. It's mainly just walking now, and I do not really have the motivation to exercise at home, it's not the same …. The first time, yes, it was all zoom and house party, but the novelty has worn off this time." (P44).*

> *"I'm not using my brain at the moment darl, it's made me lazy you know." (P806).*

3.2.3. Theme 3: anticipated brain-healthy lifestyle behaviors following COVID-19 restrictions

Participants described that COVID-19 had resulted in moments of self-reflection. Such contemplative moments had created feelings of appreciation and the determination to make positive future changes to their lifestyles once restrictions had eased. A common thread among participants would that they would do more, such as increasing travel and social activities, be outside more, do more physical activity and eat out more often. They also reflected on feelings of gratitude that life had not always been like this.

> *"It'll be just wonderful to just to do all those normal things that we took for granted." (P470).*

While many expressed the desire to just be able to do more again, some participants described that they might do things a bit differently, such as exercising caution and hesitation in what may become a new 'normal'. This was particularly apparent around continuations of COVID-safe measures and the acknowledgement that an ease of restrictions may not mean life returns to normal for them.

> *"I think I'll probably always wear a mask on public transport for the rest of my life. I feel naked without one." (P470).*

There was a sense that life would simply revert back to normal and previous activities would be able to be resumed. This was a conscious decision at times to start returning to activities participants were doing before the COVID-19 lockdowns, but among others they were simply waiting until restrictions were eased and programs were started up again. A common theme in the response to continual lifestyle adaptations post COVID-19 restrictions primarily fell under a reversion back to normal, pre-COVID-19 lifestyles, or adaptation to future changes as they arrive.

> *"I'll certainly go back to doing all the things I did before, I hope." (P775).*

> *"After lockdown I'll keep the brain going … I bought myself one of those electronic chess sets so that certainly stimulates my brain … I would get back to playing table tennis which I normally do 3 days a week so I'll get back into that." (P114).*

> *"I've always been active. I'll continue that when we get back to the real life again." (P425).*

The potential lasting impacts of COVID-19 could not be ignored by some however, as they expressed opinions that things would not change very much even after restrictions eased.

> *"Probably it will not change a great deal, I have a son who lives in England and I'm not getting over there soon, so restrictions would probably have to ease a lot before it made a big change to me." (P464).*

3.2.4. Theme 4: consideration of future brain health initiatives to minimize ongoing COVID-19 impacts on lifestyle behaviors

In response to potential ongoing negative impacts of COVID-19 on brain-healthy lifestyle behaviors, participants provided suggestions to increase the personal and online support of future lifestyle programs.

> *"Maybe there could be a particular section on how you can keep in contact with people for example Zoom, Facetime and things, maybe just have it set down and some links for specific help that you could apply for if you were impacted from COVID-19." (P308).*

Most respondents stated that adding social contact would bring benefits as it will enable substantial support of the impacted health and lifestyle behaviors as a consequence of COVID-19.

> *"I think the checking in on people is good. You know, "Hi, this is [the research program]. How are you going?" It kind of makes us go, oh right, yes, I better do something about that." (P70).*

Some respondents highlighted the value of regular phone calls or setting up of support groups to motivate and improve the social aspect of brain health. There were suggestions of greater online resources, more advice and more check-in times during the program, or the implementation of a buddy system which can help support individuals to be more socially involved.

> *"Buddy up with someone else who's doing it and grab a coffee with them." (P464).*

Others described the need to have stronger connections with local organizations and community groups to foster engagement and support.

> *"I think you could have more connection with local organisations, like council." (P24).*

Some respondents emphasized the importance of individual agency and choice in life. They believed that people have the power to individually shape their own lives and achieve their goals if they have the desire to do so.

> *"I think it's up to the individual, but if you want to do things, you can. It's a matter of getting people to take an interest in those things and try and keep themselves healthy as long as you can." (P529).*

Most respondents reflected a more uncertain and open-minded perspective. Some individuals were unclear about future directions and suggested that the topic might be better positioned within the research team as well as the diversity of individual needs and preferences, respecting individual differences and indicating reluctance to impose a one-size-fits-all approach.

> *"Oh, I really do not have an idea there really. I do not know, I honestly do not know. It depends on the individual, does it not? Some people would benefit from a bit more contact, others not, myself personally, I'm fine." (P542).*

4. Discussion

4.1. Main findings

The COVID-19 pandemic has affected the lifestyles of community-dwelling older adults in Australia with enduring influence on lifestyle restrictions which can impede brain health. The nature of identified impacts varied widely and included positive influencers (increased time at home for exercise, cooking and hobbies), however participants also expressed overarching negative impressions on their lifestyles, which centered on social isolation from stay-at-home orders, and feelings of frustration and uncertainty.

4.2. Findings in the context of existing evidence

4.2.1. COVID-19 and brain healthy lifestyles

Previous international research has identified certain aspects of our lifestyle that have been impacted by the pandemic. A worldwide online

survey disseminated across Europe, North Africa, Western Asia and the Americas, found social participation and physical activity had reduced by 42 and 24%, respectively, from pre-confinement to during confinement periods (37). Sleep quality was also reduced during this time, healthy eating habits decreased as well as a number of other measures of wellbeing (i.e., emotional status, life satisfaction) (37). Respondents also identified an unhealthy reliance on technology. There are similarities in our findings with these results and the qualitative nature of our study may offer avenues of supporting brain health, as well as general health through targeted brain health interventions, given that many areas of health are modifiable risk factors for dementia.

COVID-19 restrictions impacted negatively on the social lifestyles of older adults. This is a common finding among other studies (26, 27, 38) and is of particular concern as social isolation may contribute to exacerbation of dementia risk factors, including mental health whilst limiting social opportunities found in physical activities. It is known that an active lifestyle incorporating both physical and social activity is necessary for optimal brain health (28). There is also potential to reduce dementia risk by enhancing or maintaining cognitive reserve, and frequent social contact is a named factor (3). Given the protective nature of social connection and the importance of social integration within lifestyle modifying programs, future intervention studies to reduce modifiable dementia risk factors will need to consider uncertainties associated with emerging from social isolation alongside hesitation to participate in large social events and activities due to apprehension of contracting COVID-19.

Another detrimental impact consistent with previous research is reduced physical activity levels during home confinement (28, 37). The reductions on all levels of physical activity and greater amounts of time sitting daily (39) is described in several cross-sectional studies in Dutch, Japanese, Italian and Australian older adult samples (32, 33, 40, 41). Our study expands on this and provides insights into the personal challenges involved in adapting and managing their lifestyles to foster physical activity under these new circumstances. Participants who expressed a conscious effort to adopt strategies to negate unhealthy behaviors often focused on physical and cognitive activity, suggesting that certain brain healthy behaviors can be easily substituted and maintained compared to others. Identifying and supporting commonly accepted risk factors will have important implications for future single and multidomain dementia risk reduction programs post pandemic.

4.2.2. Ongoing impacts and adaptations after COVID-19

There were concerns expressed on the enduring effects that COVID-19 may have in the future. Our results found that during the restriction period, a large proportion of older adults made changes to adapt to the situation, such as through the use of technology and online resources, as well as ensuring interaction and mental stimulation from games, puzzles and academic pursuits. Most made deliberate attempts to adapt their exercise regime too, such as increasing walking or partaking in online exercise classes. While some participants had adjusted their lifestyle to continue to be brain healthy, others showed little adaptation, having made almost no changes to their lifestyle, and found the impacts of COVID-19 and associated restrictions overwhelming and struggled to maintain healthy habits.

Broader COVID-19 research suggests that this could be a direct health consequence of acquiring COVID-19 with pre-existing chronic conditions (respiratory, cardiovascular, neurodegenerative diseases) which creates persistent symptoms, increased frailty, poorer health and can cause long COVID-19 (42) amongst older adults. Reductions in brain healthy lifestyle may also be a characteristic of those who exhibited higher adherence to government orders (33), those with pre-existing mental health conditions (anxiety, depression and post-traumatic stress disorder) (43), subjective memory complaints (32), and those who reported difficulties with certain behaviors like sleep problems and elevated alcohol and drug use (43) throughout lockdown which may have had a compounding effect on their ability to stay engaged in a healthy lifestyle.

Following COVID-19 restrictions, for the minority of participants there was a clear eagerness to socialize and travel as soon as restrictions eased, while others exhibited feelings of caution and hesitation, which is a common finding alongside fear, avoidance and procrastination (38, 43, 44). Our results depict insights into older adults' perspectives on their lifestyles in the hope of restrictions easing and whether that would reveal a 'new normal' or if life would return to pre-COVID conditions. There were a range of expected approaches to removal of restrictions shown among the participants. This included actioning their sense of acknowledgement and renewed appreciation of life by expressing motivation to sustain the new habits that had put in place, whilst others assumed they would just resume previous activities or remained largely unaffected by the situation due to their place of residence (e.g., rural areas with minimal restrictions).

Post COVID-19 research suggests that these behaviors during confinement are critical in remaining consistent with healthy behaviors after lockdown. For example, in one study older adults who were physically active during lockdown are more likely to facilitate exercise post lockdown (45). In another, the learning of new technologies during the stay at home period increased intention to use social networking sites, with a jump from 27% pre-restrictions to 50% after restrictions eased (46). Both findings suggest significant potential to propel healthier outcomes associated with exercise and connectivity in the post lockdown context (47).

4.3. Implications

Suggestions for future brain health (intervention) programs included greater and varied online resources with content and advice around healthy lifestyle choices. Program design and structural feedback included more personal support by way of an e-newsletter or more phone calls for encouragement. A final suggestion was to expand and scale-up future programs to reach more diverse groups of people and using the program as a way to create more intimate and engaged communities.

4.4. Limitations

Our study had various limitations including the nature of recruitment and the telephone-based format. Many older adults were already interested in completing a brain health intervention program, participation in the interview was optional and the restrictions did not allow for face-to-face interviews which provide non-verbal and contextual data that could have contributed deeper meaning to participant responses (48). Although we recruited through varied

mediums including print (flyers), radio and television this may have led to a selection bias (highly educated, high socioeconomic status, lower modifiable dementia risk) and this means that our findings are not generalisable to the most vulnerable older adult populations with less (brain) healthy lifestyles and higher dementia risk. The strengths of our study are the timing of our data collection, the large sample size and high response rate (96.4%). This enabled us to explore older adults insights during the second and perhaps harsher COVID-19 lockdown period in Australia (26), rather than relying on participant recall of events. It also allowed for a variety of responses in which common themes were identified despite the variations in locality and experiences.

5. Conclusion

Considering our findings and the early evidence for the effectiveness of multidomain interventions targeting changes in lifestyle behaviors in delaying cognitive decline (4, 5, 15–18, 49), development and implementation of dementia risk programs should consider the short and long-term impediments and opportunities for lifestyle change amongst individuals, communities and healthcare systems in the post COVID-19 context. Given the reported challenges involved in maintaining a brain healthy lifestyle throughout the pandemic and likely ongoing ramifications, future action should seek to involve policy change to support and bolster the potential impact of multidomain interventions, especially as older adults adapt to the new 'normal'.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Macquarie University Human Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JS: conceptualization and funding acquisition, writing-original draft preparation, and supervision. JS and CB: methodology and formal analysis. JS, LD, and KD: validation. JS and LD: investigation and project administration. JS, LD, CB, and KD: writing-review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1205001/full#supplementary-material

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Predicting unmet activities of daily living needs among the oldest old with disabilities in China: a machine learning approach

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Background: The ageing population in China has led to a significant increase in the number of older persons with disabilities. These individuals face substantial challenges in accessing adequate activities of daily living (ADL) assistance. Unmet ADL needs among this population can result in severe health consequences and strain an already burdened care system. This study aims to identify the factors influencing unmet ADL needs of the oldest old (those aged 80 and above) with disabilities using six machine learning methods.

Methods: Drawing from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) 2017–2018 data, we employed six machine learning methods to predict unmet ADL needs among the oldest old with disabilities. The predictive effects of various factors on unmet ADL needs were explored using Shapley Additive exPlanations (SHAP).

Results: The Random Forest model showed the highest prediction accuracy among the six machine learning methods tested. SHAP analysis based on the Random Forest model revealed that factors such as household registration, disability class, economic rank, self-rated health, caregiver willingness, perceived control, economic satisfaction, pension, educational attainment, financial support given to children, living arrangement, number of children, and primary caregiver played significant roles in the unmet ADL needs of the oldest old with disabilities.

Conclusion: Our study highlights the importance of socioeconomic factors (e.g., household registration and economic rank), health status (e.g., disability class and self-rated health), and caregiving relationship factors (e.g., caregiver willingness and perceived control) in reducing unmet ADL needs among the oldest old with disabilities in China. Government interventions aimed at bridging the urban–rural divide, targeting groups with deteriorating health status, and enhancing caregiver skills are essential for ensuring the well-being of this vulnerable population. These findings can inform policy decisions and interventions to better address the unmet ADL needs among the oldest old with disabilities.

KEYWORDS

unmet needs, oldest old, ADL, machine learning, Shap

1. Introduction

As China's population ages, the country faces a significant challenge in meeting ADL needs of its older persons with disabilities. According to the 2021 seventh census, 264 million people, or 18.7% of China's total population, are aged 60 or above[1]. With an aging population, there is an increase in the number of older persons with disabilities, which can be attributed to longer life expectancies and the widespread prevalence of chronic diseases (1, 2). Data from the Research Group of the China Research Center on Aging revealed that in 2010, there were 22.15 million older persons with partial disabilities and 10.84 million older persons with significant disabilities in China, accounting for 12.75 and 6.25% of the total older population, respectively (3). It is estimated that by 2050, China will have 27 million disabled individuals aged 65 or older (4). Consequently, an increasing demand for long-term care, which serves as an essential safeguard for the quality of life and functioning of the older persons with disabilities (5), has emerged to address the surge in assistance with ADL needs. Unmet ADL needs occur when assistance is not provided or is inadequate (6).

In comparison to the considerable demand for care, the supply of long-term care in China is significantly insufficient, leading to a large number of older persons with unmet ADL needs. Institutional stagnation and the influence of Confucian culture have resulted in informal care provided by families remaining the primary source for addressing the care needs of older persons with disabilities (7, 8). However, changes in family structure and the professionalization of women have gradually diminished families' caregiving capacities (9, 10). Concurrently, formal care services, such as community care and institutional care, have not developed sufficiently to provide specialized care (8). This failure to obtain adequate assistance leads to a situation of unmet need (11). A recent study indicated that more than 50% of Chinese older persons with disabilities experience unmet ADL needs (12). Unmet ADL needs not only jeopardize older persons' health but also further increase the burden on social healthcare systems. To some extent, long-term care for older persons with disabilities has become a pressing issue in Chinese society (13).

Identifying the factors affecting unmet ADL needs is crucial for improving the care system and maintaining the health of older individuals with disabilities. On one hand, unmet needs are a key concern in the development of new care systems (14). They serve as both an essential indicator for evaluating the effectiveness of existing long-term care policies and a valuable source of information for analyzing the size and characteristics of groups not covered by the current care system. Gaining insight into the unmet needs of older persons with disabilities will provide valuable guidance for future care (15). On the other hand, unmet needs can pose serious health risks to older persons with disabilities, resulting in a greater likelihood of hospital admissions, readmissions, emergency admissions, and depression (16–19). Providing adequate care can help prevent further deterioration in the health of older people with disabilities.

Previous studies have analyzed the factors affecting unmet ADL needs, demonstrating that low educational status, low income, absence of a spouse, living alone, and ADL disabilities are associated with unmet ADL needs (20–22). Some researchers have begun to focus on the caregiving situation of older persons with disabilities in China. They have utilized large-scale data from the CLHLS, which covers various aspects of the older population, such as their health status, living conditions, and economic situation. These studies have also carefully considered feature selection to identify characteristics closely associated with the risk of unmet care needs. For instance, Zeng et al. conducted an analysis based on the CLHLS database, examining the changes in health status among Chinese oldest old between 1998 and 2008. They found that advances in medication, lifestyle, and socioeconomics might compress ADL disabilities (1). Another study by Zhu analyzed factors influencing unmet long-term care needs among the Chinese oldest old. It revealed that the risk of unmet long-term needs largely depends on the economic status of the oldest old and the willingness of caregivers to provide care (13). These studies shed light on the caregiving challenges faced by the oldest old in China and highlight the importance of addressing economic factors and caregiving willingness to ensure adequate care for this vulnerable population.

While previous studies offer important findings, there are still some gaps that require additional investigation. Firstly, there is a lack of attention to the Chinese context. With a few exceptions mentioned above, the majority of studies are based on Western settings (12). China and Western countries have significant differences in their care systems for older persons. Compared to the more developed formal care service systems in Western countries, China's formal care services are still in their early stages, with the primary responsibility for caring for older adults falling on families. There is a lack of specialized and professional care available in China (7, 8). Furthermore, many Western countries have relatively sound medical insurance systems that offer a certain level of financial support and security for older persons with disabilities. However, China's medical insurance system provides limited financial support for older persons with disabilities (23). Additionally, in Western culture, individual respect and autonomy are highly valued, and older persons with disabilities are typically encouraged to retain their autonomy whenever possible. They are encouraged to participate in care decisions and choose care options that align with their personal needs and preferences. However, in China, the focus on this aspect is relatively weak. Secondly, there is a scarcity of analysis regarding the unmet ADL needs of the oldest old with disabilities (13). Oldest old generally refers to the oldest age group among the older population, but it does not have a globally standardized age criterion, and the specific age thresholds may vary among different studies, organizations, or countries. For instance, some studies consider individuals aged 80 and above as the oldest old (1, 13), while others define the oldest old as those aged 85 and above (24). Based on existing research on the oldest old population in China (1, 13), we have defined the oldest old as individuals aged 80 and above[2].While some older persons may enjoy excellent health, many others still experience health challenges and an

1 Chart: Key Data from the Seventh National Population Census. The Central People's Government of the People's Republic of China. http://www.gov.cn/xinwen/2021-05/11/content_5605871.htm

Abbreviations: ADL, activities of daily living; CLHLS, Chinese Longitudinal Healthy Longevity Survey; SHAP, Shapley Additive exPlanations; KNN, K-Nearest Neighbor; AUROC, Area Under the Receiver Operating Characteristic Curve.

2 We also defined the oldest old as individuals aged 85 and above for the study, and the results did not show significant changes.

increased need for long-term care (25). Compared to other groups, older people with disabilities are more likely to experience unmet needs (26). In the context of limited care resources, addressing the unmet ADL needs of the oldest old with disabilities should be a priority. Thirdly, there are methodological limitations in using traditional linear models. The performance of traditional linear regression methods is often constrained due to their inability to handle high-dimensional and non-linear data. Moreover, traditional methods rely on strong assumptions, which are often inaccurate in real-world data (27).

As an important branch of artificial intelligence, machine learning offers superior predictive power compared to traditional linear models (28). Machine learning offers several advantages over traditional linear models: it is better at handling high-dimensional data; more flexible and versatile in terms of prediction functions; capable of handling redundant variation between highly correlated variables; and it transcends previous constraints related to prior distribution assumptions (29, 30). Due to its strong predictive performance, machine learning is widely employed in various fields (31), enabling the development of predictive tools related to healthcare (32). In fact, scholars have utilized machine learning to demonstrate promising predictive effects on different diseases (33, 34). Furthermore, the combination of machine learning and SHAP facilitates the analysis of the ranking of each predictor variable's importance regarding its impact on the outcome.

Unmet ADL needs for the oldest old with disabilities essentially constitute a prediction problem, and the application of machine learning is both necessary and feasible. Identifying the factors that affect unmet ADL needs for the oldest old with disabilities involves determining which variables can accurately predict unmet needs. In this regard, machine learning methods with superior predictive power are more suitable than traditional linear models for analyzing the factors affecting unmet ADL needs among the oldest old with disabilities.

However, to the best of our knowledge, there are no studies that have employed machine learning to analyze the influencing factors affecting unmet ADL needs among the oldest old with disabilities in China. In this study, we utilized six machine learning methods—Naïve Bayes, Logistic Regression, Decision Tree, K-Nearest Neighbors (KNN), Random Forest, and Gradient Boosting—to identify the factors influencing unmet ADL needs among the oldest old with disabilities in China. Naïve Bayes is a probabilistic statistical classifier based on Bayes' theorem, which assumes that features are independent of each other. Logistic Regression is a widely used linear model for binary classification problems, which predicts outcomes by fitting the relationship between features and probabilities. Decision Tree is a feature-based tree-like structure that classifies or predicts instances through a series of decision conditions. KNN model determines the category of a new sample by measuring the distance between different samples. Random Forest is an ensemble learning method that combines the predictions of multiple decision trees to improve model accuracy. Gradient Boosting is an iterative ensemble learning method that builds a powerful predictive model by progressively optimizing the prediction results. By comparing the performance of these methods, we aim to determine the most effective approach for analyzing the influencing factors affecting unmet ADL needs in this population. Our findings will contribute to a better understanding of the key factors that impact unmet ADL needs, thereby informing the government's formulation of appropriate public policies and the enhancement of caregiver knowledge and skills.

2. Methods

2.1. Study design

The data for this study were obtained from the Chinese Longitudinal Healthy Longevity Survey (CLHLS). The survey was organized and executed by the Centre for Healthy Ageing and Development Research at Peking University and the National Development Research Institute. The CLHLS started with a baseline survey in 1998 and has conducted follow-up surveys in 2000, 2002, 2005, 2008, 2012, 2014, and 2017–2018. All participants signed a written informed document and agreed to participate in the survey project. The CLHLS is well-representative, covering 23 provinces in China, with 15,874 older persons aged 65 and over interviewed in the most recent follow-up survey (2017–2018).

Using the 2017–2018 CLHLS data, a total of 2,436 oldest old aged 80 and above with disability were selected for this study. Following studies using the CLHLS, we considered older persons with disabilities as individuals who required assistance in their daily living activities for more than 3 months (35). CLHLS asked participants if they needed assistance with six activities: bathing, dressing, going to the toilet, indoor activities, continence, and eating. Participants who answered yes were then asked how long they had needed assistance. Those individuals who required assistance with any of these activities for up to 3 months were considered to be older persons with disabilities and were included in the study sample. The specific data screening process is shown in Figure 1.

2.2. Outcome variable

Unmet ADL needs were measured by participants' self-response to the question, "Do you think you currently get enough help with these six daily activities of bathing, dressing, going to the toilet, indoor activities, continence, and eating to meet your needs?" Participants' responses were categorized as "completely satisfied," "average," and "not satisfied." In line with existing studies (13, 36), we combined the "average" and "unsatisfied" categories. This was done for two reasons: firstly, the study aims to explore the factors influencing unmet needs among the oldest old with disabilities, and both "average" and "unsatisfied" responses indicate a level of unmet needs that may require external assistance to improve their care; secondly, only 20 older persons in the sample reported being "not satisfied," accounting for less than 1% of the total participants, and the combined effect had minimal impact on the results. Consequently, the outcome variables were divided into two categories: fully met (coded as 1) and unmet (coded as 0). Although this measurement may contain some subjective bias, there is substantial evidence supporting its validity as an indicator of unmet ADL needs (37).

2.3. Predictor variables

Multiple dimensions influence unmet ADL needs in older persons. Drawing from existing studies and considering data

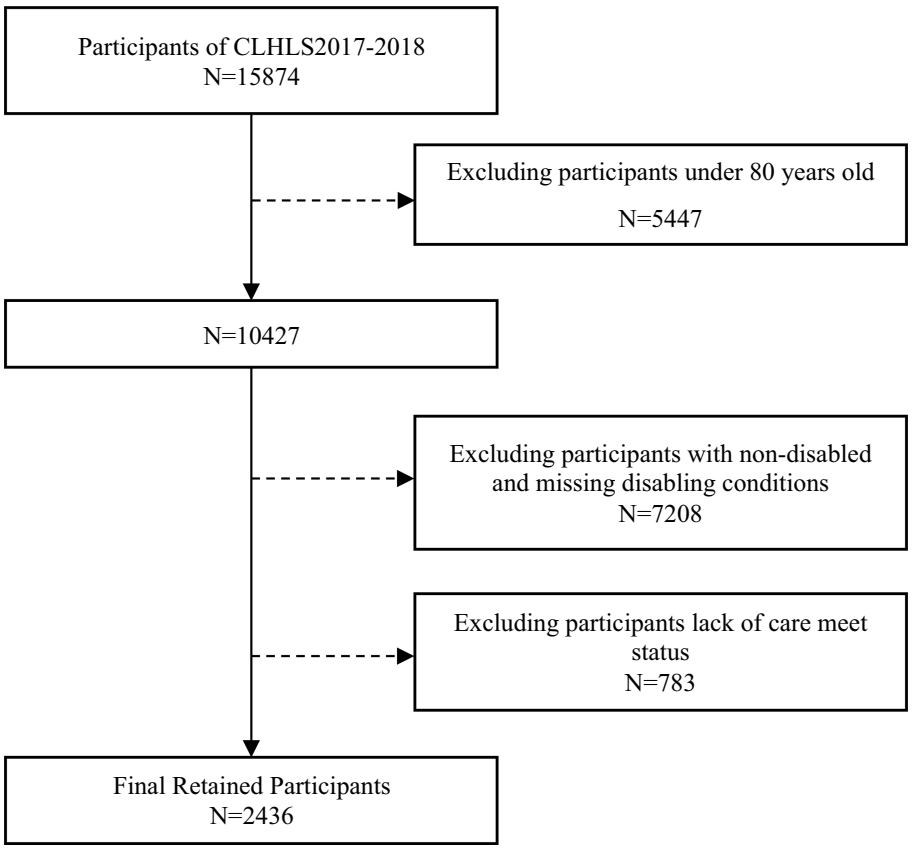

FIGURE 1
Participant Selection Flowchart.

availability (13, 36), this study selected 17 predictor variables across five dimensions: demographic, socioeconomic, health status, family relationship, and caregiving relationship. To address the small number of missing values in the predictor variables, we employed the missForest method. The missForest method has several advantages. Firstly, it can handle missing values in both numeric and categorical data simultaneously. Compared to other traditional imputation methods, missForest generally performs better in handling missing data. Additionally, missForest takes into account the correlations between variables, which allows it to perform well even in situations with a high amount of missing data or lower data quality (38).

1. Demographic characteristic variables included gender, age, and marital status. Gender is categorized as male or female. Age represents the participant's actual age. Marital status is divided into two categories: married (including married or partnered) and unmarried (encompassing never married, divorced, separated, or widowed).
2. Regarding socioeconomic characteristics, we examined household registration, educational attainment, pension, economic satisfaction, and economic rank variables. Household registration is categorized as urban or rural. Educational attainment is divided into primary school and below or junior high school and above. Pension is classified as either yes or no. Economic satisfaction is assessed based on whether the respondent feels their financial resources are sufficient, with yes or no responses. Economic rank represents the respondent's economic status within their local area, spanning five levels from very poor to very rich.
3. Health status variables encompassed self-rated health and disability class. Self-rated health refers to the participant's self-assessment of their health status on a 5-point scale, ranging from very unhealthy to very healthy. Disability class indicates the severity of the participant's disability: assistance required for 1–2 ADL tasks indicates low-level disability; 3–4 ADL tasks, medium-level disability; and 5–6 ADL tasks, high-level disability.
4. For the family relationship characteristic variables, we considered the number of children, financial support given to children, financial support received from children, and living arrangement. The number of children refers to the total number of children the participant has. Giving financial support to children denotes whether the participant provided financial support to their children in the past year, with yes or no responses. Receiving financial support from children indicates whether the participant received financial support from their children in the past year, also with yes or no responses. Living arrangement is represented by a dummy variable, divided into two categories: living with children and not living with children.
5. Regarding caregiving relationship characteristics, we selected three variables: perceived control, primary caregiver, and caregiver willingness. Perceived control refers whether the participants believe they have influence over their personal

matters, with yes or no responses. Primary caregivers are categorized into three groups: spouse, children, and other. Caregiver willingness pertains to the primary caregiver's willingness to provide care, with responses being yes or no.

2.4. Machine learning classifiers

In this study, we applied six machine learning methods to predict unmet ADL needs among the oldest old with disabilities: Naïve Bayes, Logistic Regression, Decision Tree, KNN, Random Forest, and Gradient Boosting.

1. Naïve Bayes is a widely used classification model based on Bayesian probability theory. It calculates the conditional probabilities of different independent features to classify categories. Though effective and capable of handling multi-category problems with small data amounts, Naïve Bayes is sensitive to data input methods.
2. Logistic Regression, a special case of a generalized linear model, transforms linear regression values between (0,1) by leveraging a sigmoid equation. This process turns continuous variable regression into a dichotomous task by setting a threshold.
3. Decision Tree utilize a tree structure, offering a simple and efficient classification method commonly used across various applications.
4. KNN, one of the simplest machine learning methods, classifies samples by calculating the distance between the sample and the training data points in the feature space. The sample's class is determined by the majority class among the K "nearest neighbor" points. KNN is highly accurate and requires no assumptions about data distribution; however, its computational complexity increases with larger datasets due to its reliance on distance calculations.
5. Random Forest is a typical ensemble learning method based on Bagging, suitable for addressing classification and regression problems. By constructing multiple Decision Trees, the model enhances information gain, reducing interference caused by noisy data. The random forest output is determined by the majority of Decision Tree outputs.
6. Gradient Boosting model combines multiple weak models to create more powerful and accurate ones. Gradient Boosting improves prediction accuracy by iteratively enhancing the estimation of weak models.

By utilizing these six machine learning methods, this study aims to identify the most effective method for predicting factors influencing unmet ADL needs among the oldest old with disabilities in China. The results can contribute to the development of public policies and the improvement of caregiver knowledge and skills.

2.5. SHAP: increasing interpretability

Machine learning shows impressive predictive capabilities; however, its prediction process often operates as a black box, leading to limited interpretability of the outcomes (39, 40). In other words, numerous complex machine learning algorithms create "black box models" characterized by constrained interpretability. While these models can determine the effectiveness of a specific indicator system, they cannot provide detailed explanations for individual indicators (41). To address this issue, Lundberg and Lee introduced SHAP, a tool designed to enhance the interpretability of machine learning models by calculating the contribution value of each feature and considering it as a contributor to the model's prediction. The model's final prediction is obtained by summing the contribution values of all features (42).

Owing to its robust interpretability and visual representation, the SHAP framework has been widely adopted within the machine learning domain. This explanatory model, which aligns with human intuition, has gained increasing popularity in recent years for explaining machine learning models associated with medical diagnoses, social behaviors, and other complex phenomena (43).

2.6. Data analysis

Table 1 presents the comparison between oldest old with unmet ADL needs and those without. Continuous variables are compared using a *t*-test, with results presented as mean ± standard deviation. Categorical variables are compared *via* a chi-square test, and the results are reported as the number and percentage. Statistical significance was determined using a two-tailed *p*-value of less than 0.05, indicating that the probability of obtaining the observed results by chance alone is less than 5%.

In training the machine learning method, samples were first randomly divided into a training set (70%) and a test set (30%). The optimal parameters for each model were then determined using ten-fold cross-validation in the training set. To optimize the machine learning methods, we used a combination of manual parameter tuning, grid search, and random search techniques. Manual parameter tuning involved adjusting model parameters by hand to achieve the best performance, while grid search and random search involved systematically testing different combinations of parameters to find the best combination. Ten-fold cross-validation was chosen as the method for parameter tuning because it provides a good balance between bias and variance in the estimated performance of the model. Performance of the models was assessed using evaluation metrics such as accuracy, precision, recall, F1 score, and AUROC. These metrics provided important information about the accuracy and reliability of the model's predictions. Because our outcome variable is binary (i.e., unmet ADL needs present or absent), the AUROC is a suitable evaluation metric as it measures the model's ability to correctly distinguish between positive and negative cases. The calculation formula and explanation for the above model evaluation metrics are as follows.

1. Accuracy. Accuracy measures the proportion of correctly predicted instances (both true positives and true negatives) out of the total instances.

Accuracy = (Number of Correct Predictions) / (Total Number of Predictions).

2. Precision. Precision represents the ratio of true positive predictions to the total predicted positive instances. It quantifies the model's ability to avoid false positives.

Precision = (True Positives) / (True Positives + False Positives).

3. Recall. Recall calculates the ratio of true positive predictions to the total actual positive instances. It measures the model's ability to identify all positive instances.

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TABLE 1 Descriptive statistics.

Variables	Oldest old with unmet ADL needs	Oldest old without unmet ADL needs	*p* value
Demographic variables			
Gender			
Female	821 (69.64%)	842 (66.98%)	0.160
Male	358 (30.36%)	415 (33.02%)	
Age	95.63 ± 6.63	96.29 ± 6.68	0.217
Marital status			
No	1,046 (88.72%)	1,115 (88.70%)	0.990
Yes	133 (11.28%)	142 (11.30%)	
Socioeconomic variables			
Household registration			
Rural	859 (72.86%)	713 (56.72%)	<0.001
Urban	320 (27.14%)	544 (43.28%)	
Educational attainment			
Primary and below	836 (70.91%)	768 (61.10%)	<0.001
Middle and above	343 (29.09%)	489 (38.90%)	
Pension			
No	930 (78.88%)	849 (67.54%)	<0.001
Yes	249 (21.12%)	408 (32.46%)	
Economic satisfaction			
No	243 (20.61%)	118 (9.39%)	<0.001
Yes	936 (79.39%)	1,139 (90.61%)	
Economic rank			
Very poor	36 (3.05%)	13 (1.03%)	<0.001
Poor	190 (16.12%)	72 (5.73%)	
Average	830 (70.40%)	824 (65.55%)	
Rich	107 (9.08%)	288 (22.91%)	
Very rich	16 (1.36%)	60 (4.77%)	
Health status variables			
Self rated health			
Very unhealthy	49 (4.16%)	12 (0.95%)	<0.001
Unhealthy	272 (23.07%)	180 (14.32%)	
Average	589 (49.96%)	558 (44.39%)	
Healthy	217 (18.41%)	385 (30.63%)	
Very good	52 (4.41%)	122 (9.71%)	
Disability class			
Low-level	451 (38.25%)	709 (56.40%)	<0.001
Medium-level	439 (37.23%)	396 (31.50%)	
High-level	289 (24.51%)	152 (12.09%)	
Family relationship variables			
Number of children	4.36 ± 1.98	4.47 ± 1.96	0.157
Financial support given to children			
No	312 (26.46%)	334 (26.57%)	0.952
Yes	867 (73.54%)	923 (73.43%)	

(Continued)

TABLE 1 (Continued)

Variables	Oldest old with unmet ADL needs	Oldest old without unmet ADL needs	*p* value
Financial support received from children			
No	790 (67.01%)	745 (59.27%)	<0.001
Yes	389 (32.99%)	512 (40.73%)	
Living arrangement			
Otherwise	210 (17.81%)	176 (14.00%)	0.010
Live with children	969 (82.19%)	1,081 (86.00%)	
Caregiving relationship variables			
Perceived control			
Very low	49 (4.16%)	52 (4.14%)	<0.001
Low	177 (15.01%)	146 (11.61%)	
Average	505 (42.83%)	373 (29.67%)	
High	309 (26.21%)	384 (30.55%)	
Very high	139 (11.79%)	302 (24.03%)	
Primary caregiver			
Spouse	83 (7.04%)	75 (5.97%)	0.541
Others	224 (19.00%)	247 (19.65%)	
Children	872 (73.96%)	935 (74.38%)	
Caregiver willingness			
No	198 (16.79%)	46 (3.66%)	<0.001
Yes	981 (83.21%)	1,211 (96.34%)	

Recall = (True Positives) / (True Positives + False Negatives).

4. F1 score. The F1 score is the harmonic mean of precision and recall. It provides a balanced measure of a model's performance, especially when dealing with imbalanced datasets.

F1 score = 2 * (Precision * Recall) / (Precision + Recall).

5. AUROC. ROC curves plot the true positive rate (recall) against the false positive rate as the classification threshold changes. AUROC represents the area under this ROC curve and is a good metric for assessing a model's performance across different threshold values. Higher AUROC values indicate better model performance.

Based on these evaluation indicators, we pinpointed the optimal model for predicting unmet ADL needs among the oldest old with disabilities. The optimal model provides the best balance between performance and interpretability. To understand the importance and influence of each variable on unmet ADL needs, we used SHAP to decompose the contribution of each feature to the prediction results based on the optimal model. SHAP is a useful tool for interpreting machine learning methods because it provides insights into the importance and influence of each variable on the outcome, which can help guide decision-making and policy development. The aforementioned data analysis was conducted using Stata (Stata 17 MP) and Python (Python 3.10) software platforms.[3]

3 GitHub link to the machine learning script used in this study: https://github.com/wangkun543604/predictADLneeds.git.

3. Results

3.1. Descriptive statistics

Table 1 presents the distribution of the 17 predictor variables between the unmet ADL needs present or absent oldest old. Of the total sample of 2,436 oldest old with disabilities, 1,179 (48.4%) reported having unmet ADL needs. Using a chi-square test or t-test as appropriate, significant differences were found in most predictor variables between the two groups, including household registration, educational attainment, pension, economic satisfaction, economic rank, living arrangement, self-rated health, disability class, financial support given to children, perceived control, and caregiver willingness. While there were no significant differences observed for predictor variables such as gender, age, marital status, number of children, financial support received from children, and primary caregiver, these variables may still have relevance for understanding other aspects of care needs and preferences among this population and warrant further investigation in future research.

3.2. Performance of machine learning methods

Table 2 presents the performance of six machine learning methods in predicting unmet ADL needs among the oldest old with disabilities. All models achieved AUROC values greater than 0.65 (as shown in Figure 2), indicating good predictive performance for unmet ADL needs among the oldest old with disabilities. These results compare favorably to previous studies on the topic and suggest that machine

TABLE 2 Predictive performance of six machine learning models.

Model	Accuracy	Recall	Precision	F1 score	AUROC
Random Forest	0.702	0.660	0.735	0.696	0.752
Gradient Boosting	0.670	0.658	0.689	0.673	0.740
Logistic Regression	0.651	0.716	0.646	0.679	0.733
Naïve Bayes	0.644	0.782	0.624	0.694	0.721
Decision Tree	0.647	0.700	0.645	0.672	0.718
KNN	0.614	0.639	0.623	0.631	0.653

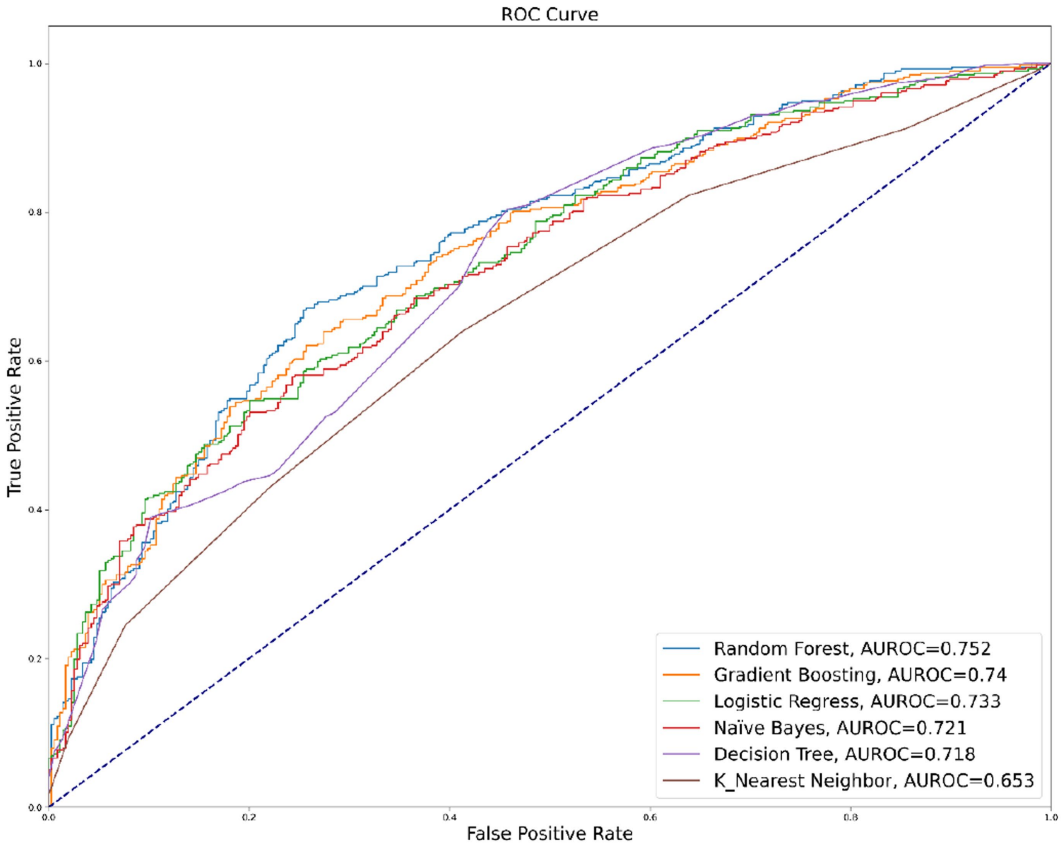

FIGURE 2
AUROC of Six Machine Learning Models.

TABLE 3 Parameters of six machine learning model.

Model	Parameters
Random forest	n_estimators = 94, max_depth = 6, max_features = 0.1, min_samples_split = 9
Gradient boosting	n_estimators = 97, min_samples_split = 18, min_samples_leaf = 11, max_features = 0.2, max_depth = 7, learning_rate = 0.05
Logistic regression	solver = newton-cg, C = 0.001
Naïve bayes	var_smoothing = 0.1
Decision tree	max_depth = 7, max_features = 15, min_samples_split = 16, min_samples_leaf = 14
KNN	n_neighbors = 9

learning algorithms can be effective tools for predicting unmet ADL needs in this population. Among the six models tested, the Random Forest model achieved the highest AUROC (0.752) and good accuracy (0.702), recall (0.660), and precision (0.735) scores, indicating that it was the most effective model for predicting unmet ADL needs among the oldest old with disabilities. The results demonstrate the potential of machine learning methods, particularly the Random Forest model, in predicting unmet ADL needs among the oldest old with disabilities.

Table 3 provides the specific parameters for the six models used in this study. In this study, only a small number of parameters were tuned,

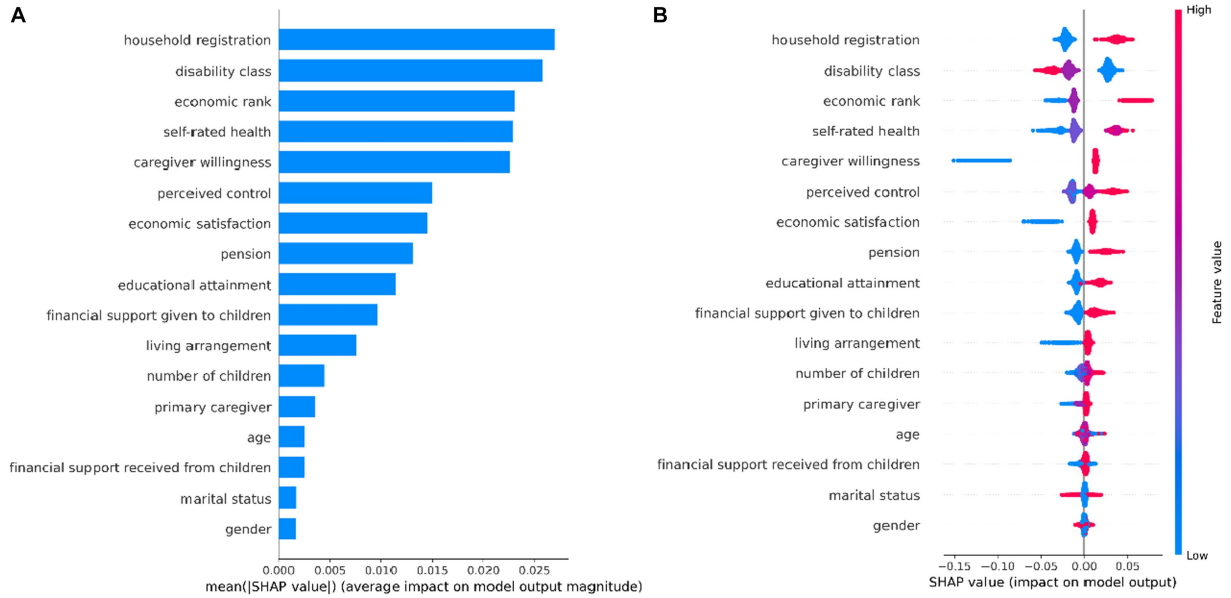

FIGURE 3
Variable Importance in Random Forest Model. **(A)** Mean SAHP value **(B)** SHAP value.

and the default settings were kept for the rest of the parameters. For instance, the Random Forest tuning parameters used a grid search to determine the optimal parameters n_estimators (n_estimators = 94), max_depth (max_depth = 6), max_features (max_features = 0.1), and min_samples_split (min_samples_split = 9).

3.3. Feature importance

To gain insights into the factors influencing unmet ADL needs among the oldest old with disabilities, we used SHAP to learn how individual variables contributed to the Random Forest model's prediction. Figure 3A shows that the factors influencing unmet ADL needs among the oldest old with disabilities, in order of importance, are: household registration, disability class, economic level, self-rated health, caregiver willingness, perceived control, economic satisfaction, pension, educational attainment, financial support given to children, living arrangement, number of children, primary caregiver, financial support received from children, age, gender, and marriage.

As seen in Figure 3B, the likelihood of having unmet ADL needs was higher among the oldest old with the following characteristics: rural household registration, high disability class, low economic class, poor self-rated health, low caregiver willingness, low perceived control, low economic satisfaction, having no pension, low education level, not giving children possessions, living without children, having less children, and having others as primary caregivers. Receiving financial support from children, age, gender, and marriage were not significantly associated with unmet ADL needs among the oldest old with disabilities. These findings provide valuable insights into the factors that influence unmet ADL needs among the oldest old with disabilities. By identifying key factors associated with unmet ADL needs among the oldest old with disabilities, the results of this study can inform the development of targeted interventions and policies aimed at improving the quality of care for this vulnerable population. For example, policymakers may use this information to prioritize funding for support services or programs that address the specific needs of older persons with disabilities and improve their overall care status.

4. Discussion

Aging is indeed a prevalent issue faced by societies worldwide, and the likelihood of disability in older person tends to increase with age (43, 44). Providing adequate care for older persons with disabilities is crucial for maintaining their dignity and quality of life. In this context, identifying the factors affecting unmet ADL needs and developing appropriate responses is essential.

Existing studies have extensively explored this issue using linear models (12–14). However, these models have limitations in identifying the nonlinear effects of variables, and the magnitude of variable coefficients may not accurately measure the relative importance of variables. Additionally, many studies have identified variables that influence outcomes without prioritizing their importance (12, 13). In the context of limited care resources, determining the relative importance of factors affecting unmet needs is a necessary step to optimize resource utilization. Machine learning algorithms, such as the Random Forest model, can help address these limitations by identifying complex relationships between variables and ranking their relative importance. This enables policymakers and care providers to prioritize interventions and allocate resources more effectively, ultimately improving the quality of life for older persons with disabilities.

Machine learning is an important branch of artificial intelligence. In the era of complex big data, machine learning plays an increasingly crucial role in the field of geriatric health due to its powerful predictive capabilities. For example, Xin and Ren analyzed the main factors influencing depression among older persons with disabilities in rural and urban China using the Random Forest model (45). Lin et al. employed multiple machine learning methods to analyze depression factors in a home-based older population (46). Kitcharanant et al. utilized machine learning to analyze mortality in older persons within 1 year after

experiencing a fragility hip fracture (47). These studies demonstrate the potential of machine learning to improve prediction and analysis in geriatric health.

Similarly, in this study, the machine learning model achieved impressive results. Six machine learning models - Naive Bayes, Logistic Regression, Decision Tree, KNN, Random Forest, and Gradient Boosting - were employed in the analysis. The AUROC values for all models were greater than 0.65, indicating good prediction performance. Among them, the Random Forest model had the best prediction with an AUROC of 0.752, accuracy of 0.702, recall of 0.660, and precision of 0.735. The strong predictive power of the machine learning models in this study is consistent with the results of previous studies, which have demonstrated the potential of machine learning algorithms in predicting the outcomes of interest in geriatric health research (45–47).

To further investigate the factors influencing unmet ADL needs among the oldest old with disabilities, this study used SHAP based on the Random Forest model with the optimal predictive performance. The results identified household registration, disability class, economic status, self-rated health, caregiver willingness, perceived control, economic satisfaction, pension, educational attainment, financial support given to children, living arrangement, number of children, and primary caregiver as the factors influencing unmet ADL needs among the oldest old with disabilities, in order of importance. These findings provide valuable insights into the factors that contribute to unmet ADL needs in this population and can guide policymakers and care providers in developing targeted interventions and allocating resources effectively. It is noteworthy that receiving financial support from children, age, gender, and marriage were not significantly associated with unmet ADL needs among older persons with disabilities. Our findings are consistent with some studies, but there are also differences.

The association between household registration and unmet ADL needs is consistent with the study by Zhu and Oesterle (14), who found a significant association between urban and rural household registration on unmet needs in China. Disabled people with rural household registration were more likely to have unmet needs than those with urban household registration. Hu and Wang found older people living in rural communities have a higher level of unmet needs than those in urban communities (19). In addition, Chen et al. also found rural older females are more likely to experience unmet needs compared with urban counterparts (36). Possible reasons for this include the large exodus of young laborers from rural China, leading to spatial distancing of offspring from older persons (48), and a dramatic shrinkage of family caregiving capacity. Additionally, weaker affordability and accessibility of formal care for rural residents make them less likely to receive formal care (14, 49).

The study by Schure et al. has also found an association between the disability class and unmet ADL needs (50). Individuals with more severe disabling conditions are more likely to experience unmet ADL needs, and the determinants of inadequate care versus no care differed with respect to disability class (21). Hu and Wang found disability class affects both the likelihood and the level of unmet needs (19). This result is not surprising, given the strong correlation between disability status and the level of ADL needs. Similar to the disability class, self-rated health is a significant predictor variable of unmet ADL needs. This finding is consistent with Zhu's study (13). In Peng et al.'s study, having good self-rated health also reduced the risk of unmet care (12). The logic behind this association is that the poorer the self-rated health of older persons with disabilities, the stronger the need for ADL assistance, and the higher the likelihood of unmet ADL needs.

In addition to household registration, the socioeconomic dimension factors of economic rank, economic satisfaction, pension, and educational attainment were all significantly associated with unmet ADL needs. Desai et al. also have found an association between economic status and unmet ADL needs (51). Zhu's study also revealed that the risk of unmet long-term needs largely depends on the economic status of the oldest old (13). But in Momtaz et al.'s study, household income was not found to be a significant predictor of unmet need (22). This difference may be due to differences in country contexts. Given the substantial resources required for long-term care, individuals in poorer economic status are more likely to experience unmet need. At the same time, this also reflects, to some extent, a shift in China's care system, where money has naturally become a major factor in unmet ADL needs as family caregiving capacity has shrunk.

Apart from objective health and financial status, caregiver willingness and perceived control, which reflect the caregiving patterns of the older persons with disabilities, are important variables in predicting unmet ADL needs. Existing studies also found a significant association between caregiver willingness and unmet needs (12, 13). Caregiver willingness affects the quality of caregiving services, which in turn affects the unmet ADL needs among the older persons with disabilities. Perceived control, which allows the older persons with disabilities to make requests that are more in line with their care needs, was found to be significantly associated with unmet ADL needs in this study. This highlights the importance of taking into account the preferences and needs of older persons with disabilities in caregiving, which may reduce the risk of unmet ADL needs.

In terms of the family relationship, this study found that providing financial support to children was significantly associated with unmet caregiving needs among the oldest old with disabilities. This finding aligns with the intergenerational exchange theory, where providing financial support to children is associated with better caregiving services. In Chen et al.'s study, higher income levels for caregivers also reduced the likelihood of unmet care need (36). Moreover, the number of children was also significantly associated with unmet ADL needs. This finding is consistent with Peng et al.'s study (12). Lima and Allen's research also shows that availability of social support were key factors related to a situation of no care (21). Older persons with more children tend to have greater access to family caregiving resources and are less likely to have unmet ADL needs.

Interestingly, this study found weak associations between age, marital status, and gender with unmet ADL needs, which is inconsistent with Chen et al.'s findings (36). Momtaz et al. found that age was not a significant predictor of unmet needs (22). In Peng et al.'s study, age and marital status were also not significantly associated with unmet needs (12). These may be attributed to the fact that the sample population in this study consisted of older persons with disabilities aged 80 years and above, where the biological factors of age and gender might have less influence on their health. Additionally, it can be challenging for older persons' spouses to provide effective caregiving support.

Compared to previous studies, this study offers the following advantages: Firstly, it introduces machine learning to analyze factors affecting unmet ADL needs among the oldest old with disabilities. Machine learning models offer stronger predictive power without requiring additional model assumptions, unlike traditional linear models. Secondly, the study combines six machine learning algorithms, including Naïve Bayes, Logistic Regression, Decision Tree, KNN, Random Forest, and Gradient Boosting, to ensure robust results. Among these models, Random Forest demonstrated the most effective predictive performance. Lastly, by combining machine learning with SHAP, this study builds an interpretable model, allowing for a thorough exploration of the

importance and influence of different factors on unmet ADL needs among the oldest old with disabilities.

However, this study has some limitations that should be acknowledged. Firstly, the context of the study is limited to China, and the findings may not be generalizable to other countries due to the unique cultural, social, and economic characteristics of China. For instance, while household registration is a significant predictor of unmet ADL needs among the oldest old with disabilities in China, it may have limited relevance for other countries due to its unique nature. Secondly, this study focuses on the oldest old with disabilities, which may not reflect the situation of younger older persons with disabilities. While age and marital status were not predictor variables affecting unmet ADL needs among the oldest old with disabilities, this may differ for the younger old group. Lastly, the study did not include all possible factors that may influence unmet ADL needs, and future research should explore additional variables to gain a more comprehensive understanding of the factors affecting unmet ADL needs among the oldest old with disabilities. Despite these limitations, this study provides valuable insights into the factors associated with unmet ADL needs among the oldest old with disabilities, which can inform policies and interventions aimed at improving the quality of life for this vulnerable population.

Our study on predicting unmet ADL needs among the oldest old with disabilities in China holds crucial policy implications. Firstly, optimizing resource allocation is paramount to address disparities in access to care and support. The factors of household registration and economic rank were found to be associated with unmet ADL needs. Policymakers must focus on equitable distribution of resources, ensuring that economically disadvantaged and remote regions have adequate support and services available to meet the needs of older persons with disabilities.

Secondly, tailored care and support for individuals with different disability classes are essential to address their specific requirements. Customized rehabilitation programs and welfare measures must be implemented to cater to the diverse needs of each disability group. By acknowledging and addressing these unique needs, policymakers can enhance the overall well-being and quality of life for the oldest old with disabilities in China.

Thirdly, to bolster the overall support system, policymakers should emphasize the importance of economic security for older adults. Improving pension schemes and providing additional financial aid to those in need can significantly reduce financial burdens and enable older individuals to better cope with their ADL requirements. This approach will foster a more dignified and supportive environment for the oldest old with disabilities.

In conclusion, addressing unmet ADL needs among the oldest old with disabilities in China requires a multifaceted approach. Policymakers must optimize resource allocation, provide tailored care and support, and strengthen economic security to enhance the well-being and quality of life of this vulnerable population. By implementing these policy measures, the government can create a more inclusive and supportive society for the oldest old with disabilities, fostering their independence and overall happiness in their later years.

5. Conclusion

This study employed six machine learning methods to predict unmet ADL needs among the oldest old with disabilities in China, with the Random Forest algorithm demonstrating the highest prediction accuracy. The analysis identified critical factors influencing unmet ADL needs, emphasizing the importance of addressing socioeconomic disparities, health status, and caregiving relationship factors. To alleviate unmet ADL needs, our findings suggest that government interventions should focus on bridging the urban–rural divide, supporting those with deteriorating health status, and enhancing caregiver skills and resources. The study's results can guide policymakers and stakeholders in designing and implementing effective interventions to improve the well-being and quality of life for the oldest old with disabilities in China. Furthermore, the machine learning approach showcased in this study can be adapted and utilized in other countries and regions to better understand and address the unmet ADL needs of their ageing populations.

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 ethics committee of the Institutional Review Board, Duke University (Pro00062871), and the Biomedical Ethics Committee, Peking University (IRB00001052–13074) approved all the procedures. All methods were performed in accordance with the relevant guidelines and regulations. Informed consent was obtained from both the literate participants and the legal guardian/next of kin of illiterate participants.

Author contributions

KW: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization. JZ: Writing – original draft, Writing – review & editing, Visualization. JH: Writing – original draft, Writing – review & editing, Methodology. DL: Writing – review & editing, Visualization. YL: Writing – review & editing, Conceptualization, Formal Analysis, Funding acquisition, Project administration, Supervision.

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Conflict of interest

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

Publisher's note

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Are men dominant? Evidence of differences between physical activity and quality of life among older adults in China

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At present, the aging population is one of China's basic national concerns, and physical exercise offers endless potential to cope with it. However, the life expectancy of men in China is generally lower than that of women, and the health status of older men is more worrying. Could it be that differences in physical exercise cause the difference in life expectancy between older men and women? This study analyzes the exercise regimen of older men and women and its influence on their quality of life. Approximately 200 respondents aged over 60 were investigated using the SF-36 and exercise questionnaires. Our findings revealed the following: (1) The scores of seven dimensions of life quality of older men were significantly lower than those of older women ($p < 0.001$), but there was no significant difference only in physiological function ($p > 0.05$); (2) The exercise frequency and persistence of older men were significantly lower than those of older women ($p < 0.001$), but there was no significant difference in exercise time ($p > 0.05$); and (3) All eight indices of quality of life of older men were positively correlated with the four indices of exercise ($0.250 < R < 0.597$). Our study offered the following conclusions: (1) The health of older men who lack physical exercise is poor. From the perspective of healthy aging, older men are a vulnerable group that deserves more attention. (2) Within an appropriate range, the more older men participate in physical activity programs, the more conducive they are to improved health. (3) This study focuses on promoting physical exercise for older adults and suggests organizing them to participate in sports activities as an important measure to promote healthy aging in China.

KEYWORDS

aging population, older men, healthy, exercise, SF-36, healthy aging

1. Introduction

China has the largest aging population in the world. Along with the increasing aging, the associated health problems place an extremely heavy burden on the whole country (1). The results of the seventh national census show that "China's population aged 60 and above exceeds 260 million, accounting for 18.70% of the population, and aging is intensifying" (2). In this context, how to achieve healthy aging in an economical and effective manner is a major dilemma that China faces. Cognizant of the challenges posed by population aging, the Chinese government has given its full consideration and attention to it. It has incorporated development strategies and countermeasures that address aging when formulating the National Economic and Social Development Plan; it has prioritized the wellbeing of the older population to ensure they enjoy a healthy old age (3). In the "Health China 2030 Plan," "strengthening health services for key populations" explicitly mentions the need to

"promote healthy aging." The plan proposes to "strengthen the integration of physical medicine and non-medical health interventions" and "promote physical activities for... the older... and other key populations" (4). Therefore, the development of sports and physical activities for the older adult population is an important way to promote healthy aging in China. Furthermore, it is a topic worthy of in-depth study that can help promote national fitness and aid China in becoming a "strong sports nation" (5).

With a growing aging population and national attention on it, the health status of this demographic has attracted extensive academic attention and research. Numerous studies have shown that regular physical activity has many health benefits for older adults, such as improving physical and mental health (6), preventing diseases (7), and reducing the risk of chronic diseases (8, 9). According to experts, middle-aged and older adults who participate in at least 150 min of moderate-to-vigorous physical activity per week can reduce mortality by 31%, the rate of cognitive decline by about 1/3, the risk of stroke by 15%, and the relative risk of activity limitation by 50% (7).

Studies on population longevity have shown that women live significantly longer than men and there are significant differences in health parameters between older men and women (10). In Chinese tradition, women are considered weak, and men are considered strong. Therefore, it is customary to focus more on women, which has resulted in not enough attention being paid to men, their physical fitness, and their health, leading to their neglect (11). In the existing literature, there are many studies focusing on the health and physical education of older adults. However, from a gender perspective, researchers have neglected promoting the health and physical exercise of older men. In particular, literature combining physical exercise and health for older men is scarce. In order to achieve comprehensive healthy aging, the health of the entire aging population must be studied and promoted. Therefore, this study aims to analyze the physical exercise regimen of older men and the effect it has on the quality of their life from the perspective of gender differences in order to provide a reference for promoting the quality of life of older men and achieving healthy aging in China.

2. Materials and methods

2.1. Participants

The target population of this study was older adults. In order to analyze from a gender perspective, the survey population was recruited using male and female pairs to select 200 older adults aged over 60 years (paired older people were drawn from the same community). In order to control the influence of irrelevant variables such as community environment, the questionnaire survey selected several communities in Xi'an with minimal differences between them in living conditions for questionnaire distribution. Inclusion criteria included being able to move around the community without barriers, agreeing to participate in the questionnaire, having some cognitive ability, and being able to answer the investigator's questions. Exclusion criteria included the presence of cognitive impairment, unable to effectively answer the investigator's questions, and the presence of physical disability or apparent disease. The basic information of the survey respondents is shown in Table 1.

2.2. Measurement tools

The Quality of Life Assessment uses the SF-36 Quality of Life Self-Measurement Scale issued by the World Health Organization. There are 36 questions with eight dimensions, including Physical Functioning (PF), Role-Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Social Functioning (SF), Role-Emotional (RE), and Mental Health (MH). While PF measures whether health conditions interfere with normal physical activities, RP measures functional limitations due to physical health problems, and BP measures pain levels and the impact of pain on daily activities. On the other hand, GH is a subjective measure of the respondent's evaluation of his or her own health status and future health trends. VT measures the individual's subjective feelings about their energy and fatigue levels, and SF measures the individual's social function in terms of the impact of physical and psychological problems on the quantity and quality of the individual's social activities and is used to evaluate the effect of health on social activities. RE measures the functional limitations due to emotional problems, while MH measures whether the respondent is mentally healthy and assesses whether the individual is mentally tense, depressed, or restless and whether the individual is happy and calm. The first four dimensions together reflect the physical health of the respondent, and the last four dimensions observe the person's mental health. The consistency reliability coefficient of the scale was 0.72–0.88, and the 2-week retest reliability was 0.66–0.94 (12). The scoring method of the SF-36 was adapted from the method introduced by Chonghua Wan in Introduction to Commonly Used Quality of Life Measurement Scales (13).

The physical exercise behavior assessment uses four indicators, including exercise items, exercise time, exercise frequency, and exercise behavior stage. The exercise item test question included questions such as: "The items you often participate in physical exercise (multiple choice): (1) running, (2) basketball, (3) soccer, (4) table tennis, (5) badminton, (6) swimming, (7) aerobics, (8) dance, (9) martial arts, (10) taijiquan, (11) qigong, (12) yoga, (13) walking, (14) gateball." Exercise time refers to the time spent on physical exercise each time, and it included test question such as: "Usually, the time you take part in physical exercise each time: (1) 15 min, (2) 15 to 30 min, (3) 30 min to 1 h, (4) 1 to 1.5 h, (5) more than 1.5 h." Exercise frequency refers to the number of times the respondents participated in physical exercise each week, and it had test questions such as: "Usually, you participate in physical exercise each week: (1) <once, (2) once, (3) twice, (4) three times, and (5) four times and more." The exercise behavior stage measurement question included questions such as: "Regular physical exercise is defined as planned physical activity to promote health, such as walking, jogging, ball games, and other activities". Effective exercise should be adhered to more than three times

TABLE 1 Basic information of survey respondents ($n = 200$).

Basic information*	Category	Number of people	Proportion
Gender	Male	100	50%
	Female	100	50%
Age	60–64 years old	66	33%
	65–69 years old	38	19%
	70–74 years old	39	19.5%
	75–79 years old	32	16%
	80 years old and above	25	12.5%
Academic qualifications	Primary school	16	8%
	Junior high school	49	24.5%
	High school	48	24%
	Secondary school	31	15.5%
	College	34	17%
	Undergraduate	19	9.5%
	Graduate and above	3	1.5%
Working situation	On-the-job	16	8%
	Retired	184	92%

*Data information: Xi'an City, Shaanxi Province, 2017.

a week, and each time, more than 20 min can make you sweat. According to this definition, do you perform regular exercise? 1. Yes, I have been adhering to such physical exercise for more than 6 months. 2. Yes, I have not been adhering to such physical exercise for more than 6 months. 3. No, I participate in some physical exercise, but not on a regular basis. 4. No, but I intend to start physical exercise. 5. No, and I have no intention to start physical exercise" (14).

2.3. Data analysis

Data analyses were performed using SPSS for Windows version 26.0. Statistical methods mainly used independent sample t-test and Pearson correlation analysis. Specifically, first, an independent sample t-test was used to compare the mean values of the 8 dimensions of quality of life scores between older men and women and to test whether there was a significant difference in the quality of life of older adults by gender. Second, an independent sample t-test was used to analyze the comparison of the mean values of the number of sports, exercise frequency, exercise time, and exercise persistence between older men and women and to test whether there was a significant difference in the physical activity behavior of the study participants by gender. Finally, Pearson correlation analysis was used to analyze the correlation between the quality of life and physical activity behavior of older men. The analysis was aimed to determine the significant effects of different numbers of sports programs, exercise frequency, exercise time, and exercise persistence on the quality of life scores of older men assessed across the eight dimensions.

3. Results

3.1. Comparative analysis of the quality of life of older men and women

The Quality of Life Measurement Scale assesses a number of aspects of physical, mental, and social health. Table 2 provides the results of the statistical analysis of the independent samples t-test for the scores of the eight dimensions of quality of life in older men and women. From the statistical results, it is apparent that older men scored significantly lower ($p < 0.001$) than older women in 7 dimensions of quality of life, including Role-Physical (41.75), Bodily Pain (51.50), General Health (56.65), Vitality (64.20), Social Functioning (77.50), Role-Emotional (62.66), and Mental Health (65.36), with a non-significant difference ($p > 0.05$) only in Physical Functioning (75.70). This indicates that the quality of life of older men is poor, and as a health-disadvantaged group, they should be the focus of attention from the perspective of healthy aging.

3.2. Comparative analysis of physical activity behavior of older men and women

The physical activity behavior assessment includes the following four indicators: exercise items, exercise frequency, exercise time, and exercise behavior stage. The exercise items include the names of the sports items, which are used to calculate the number of sports items the subjects participate in; the exercise frequency is used to analyze the number of times the subjects participate in physical exercise in a week; the exercise time is used to analyze the length of time the subjects participate in each

TABLE 2 Independent sample *t*-test for quality of life in older men and women.

	Older men		Older women		*t*	sig
	Mean	St.d	Mean	St.d		
Physical Functioning (PF)	75.700	17.437	77.750	15.397	−0.881	0.379
Role-Physical (RP)	41.750	35.543	72.250	38.088	−5.855	0.000
Bodily Pain (BP)	51.500	13.734	64.500	13.734	−6.693	0.000
General Health (GH)	56.650	11.504	62.750	7.797	−4.389	0.000
Vitality (VT)	64.200	12.221	72.900	11.938	−5.092	0.000
Social Functioning (SF)	77.500	21.022	93.500	18.333	−5.736	0.000
Role-Emotional (RE)	62.660	37.084	83.992	30.141	−4.464	0.000
Mental Health (MH)	65.360	11.317	72.800	11.456	−4.620	0.000

TABLE 3 Independent sample *t*-test for physical exercise behavior of older men and women.

	Older men		Older women		*t*	sig
	Mean	St.d	Mean	St.d		
Sports items	1.400	0.651	1.900	1.068	−3.996	0.000
Exercise frequency	2.920	1.022	3.960	0.898	−7.645	0.000
Exercise time	2.940	0.930	3.080	0.837	−1.119	0.265
Exercise adherence	3.150	1.077	4.220	0.970	−7.384	0.000

physical exercise; and the exercise behavior stage is used to analyze whether the subjects engage in regular, healthy and planned physical exercise.

Table 3 gives the results of the statistical analysis of the independent sample *t*-test for the physical activity behavior of older men and women. From the statistical results, it is evident that older men scored significantly lower than older women in the number of participating sports (1.40), exercise frequency (2.92), and exercise adherence (3.15) ($p < 0.001$). The difference in exercise time (2.94) was not significant ($p > 0.05$). It indicates that the current physical exercise behavior of older men is less than that of older women. In terms of the mean value, the number of sports items that older men frequently participate in is 1.4; the number of times they participate in physical exercise per week is mainly 1 to 2 times; the duration of each participation in physical exercise is mainly within 30 min; and the stage of exercise behavior is mainly in the preparation stage, which is expressed as "participating in some physical exercise, but not regularly." This is consistent with our observation that older men participated less in physical activity compared to women.

3.3. Correlation analysis of quality of life and physical activity in older men

In order to analyze whether there is a relationship between the poor quality of life of older men and their lack of physical exercise, the correlation between their quality of life and physical exercise behavior data was conducted, and the results of the analysis are shown in Table 4. From the data in Table 4, it can be seen that all eight indicators of quality of life of older men have a significant positive correlation with four indicators of exercise behavior ($0.250 < R < 0.597$). The correlation coefficients of Physical Functioning, General Health, Vitality, Social Functioning, Mental Health, and exercise behavior reached 0.001. This indicates that, within the scope of their ability, the more older men participate in physical exercise programs, the more frequently they exercise, the longer the duration of each physical exercise, and the longer they persist in exercising, the better their quality of life would be.

4. Discussion

4.1. Quality of life for older men requires focused attention

With an increasing aging population, the health of older adults in China has been of much concern and research. However, the influence of traditional Chinese concepts such as "strong male and weak female" has often resulted in the neglect of older men. From the results presented in Table 1, it can be seen that the scores of older women in the eight dimensions of quality of life are higher than for men, and there are significant differences between older men and women in the remaining seven dimensions except for physiological function (PF), which indicates that the current health condition of older men is not optimistic. The ability of older men to cope with adverse events decreases with age. For example, adverse events such as retirement, widowhood, and family discord can have significant effects on older men's physical functioning (RP), social functioning (SF), somatic pain (BP), general health self-assessment (GH), and emotional functioning (RE) (15). It has also been suggested that anxiety is more severe among older men without a spouse (16). After the transition from middle age to old

TABLE 4 Correlation analysis of quality of life and physical activity in older men.

	PF	RP	BP	GH	VT	SF	RE	MH
Sports items	0.429***	0.253*	0.203*	0.369***	0.377***	0.369***	0.262**	0.413***
Exercise frequency	0.502***	0.253*	0.333**	0.518***	0.593***	0.474***	0.231*	0.471***
Exercise time	0.597***	0.321**	0.284**	0.278**	0.524***	0.492***	0.422***	0.492***
Exercise adherence	0.395***	0.250*	0.333**	0.465***	0.585***	0.391***	0.226*	0.487***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

age, health concerns are often not as important as those of women of the same age, and there are relatively few exercise prescriptions for older men (17). Currently, more and more older men are suffering from cardiovascular diseases, which are caused by bad habits such as socializing, drinking, and staying up all night during middle age, which affect their energy (VT) and body pain (BP) and often affect their work and daily life. As older men shoulder important family responsibilities, they deserve more attention (18). In recent years, the country has actively implemented a national strategy to cope with population aging and integrated the concept of positive and healthy aging into the whole process of economic and social development (19). Meanwhile, in the context of general health, the poor quality of life of older men is a serious problem, and as a vulnerable group, they deserve the attention of society.

4.2. Lack of physical activity in older men predisposes them to poor quality of life

The reasons for the poor health of older men are many. On the one hand, it is related to their age, where with the progression of age, their physical condition declines, and the function of the body organs gradually deteriorates, resulting in poor health. On the other hand, men tend to assume more responsibility in society and family, balancing work and family commitments. However, they are also prone to various chronic diseases caused by their overwork and exertion. For example, stress can lead to heart disease and stroke in older adults reducing the quality of life (20). Another very important reason is the lack of physical activity (21). Table 2 shows that the number of physical exercise programs for older men (1.40) is lower than the number of physical exercise programs for older women (1.90), which is consistent with the existing research literature. In other words, the choice of physical exercise programs for older women is richer, while the choice of physical exercise programs for older men is relatively limited. The study by Li and Guan (22) found that older men's lack of interest in sports programs and their numerous responsibilities contribute to their lack of exercise.

Table 2 shows that the frequency of physical exercise in older men (2.92) is lower than that of older women (3.08). Compared to women, older men are generally less physically active in their daily lives. In recent years, older women were found to have more free time after retirement than before, which allowed them to participate in sports more (23). In contrast, older men in the same age category are less involved in physical activity compared to women. Some studies have shown that one of the important reasons for the low frequency of physical activity among older men is related to the lack of scientific knowledge of exercise (24). In addition, factors such as bad weather, congested traffic, and lack of guidance from community sports personnel are also important factors that affect the frequency of physical activity among older adults (25). Table 2 also reveals that older men's exercise persistence (3.15) is significantly lower than that of older women (4.22). Some studies suggest that the degree of improvement of the public sports service system affects older men's motivation to participate in physical exercise (26), which in turn affects their exercise persistence. For example, most of the sports provision for older men is in squares, parks, and fitness venues in the community. However, the supply of public sports venues, fitness centers, and clubs for older men is not perfect, and the lack of or damage to sports venues and sports equipment facilities is one of the important reasons for their lower exercise adherence. This series of problems can affect older men's behavior of engaging in physical exercise, which in turn affects their quality of life. Inadequate physical activity in older men leads to poor quality of life, and the role of physical activity on physical health should not be ignored.

4.3. Strengthening sports services for older men to improve their quality of life

Physical education is an important means of promoting human development and health. Not only does physical exercise improve one's physical health and physical activity, but physical exercise can also relax the brain, relieve psychological stress, eliminate tension, develop a positive outlook on life, and thus improve mental health. More studies have confirmed that physical activity can effectively promote the quality of life of individuals (27, 28). For example, Wang et al. (29) analyzed the factors influencing the quality of life of secondary school teachers in Lanzhou City and found that the scores in each domain tended to increase as the duration of exercise increased. O'Brien et al. (30) undertook a 1-year quality of life and health status survey of COVID-19 inpatients and also argued that physical activity at suboptimal levels facilitated the recovery of some objective physical functions. Min-Hsiung Chen found that regular physical activity increased bone mineral density in older men, thereby reducing the incidence of osteoporosis (31). Li (17) proposed that active scientific exercise in older adults can effectively improve the function of various systems, achieve physical and

mental health, and improve the quality of life. Similarly, Li (32) proposed that physical exercise as a form of social activity effectively increases the social communication opportunities of older adults and has a positive impact on them. Liu (33) proposed in the study of the effect of physical exercise on the quality of life of older adults that the effect of physical exercise on the physiological health of older adults was significantly correlated. Furthermore, older adults with a high amount of physical exercise had fewer chronic diseases, and the correlation analysis of our study on the quality of life and physical exercise (Table 3) further confirmed that physical exercise also had a significant contribution to the quality of life of older men.

There are many studies suggesting that older adults should increase the frequency and duration of physical activity (34, 35). To promote healthy aging, enhancing the time of physical exercise, frequency of physical exercise, and duration of physical exercise among older men should be the main goal. Furthermore, strengthening the sports support services for older men and organizing the participation of older men in sports activities should be implemented as an important measure. The main measures should be reflected in three major aspects, including promoting the scientific nature of exercise, improving the richness of exercise programs, and improving venue facilities.

First, using modern information technology, efforts should be made to publicize, promote, and raise awareness of the scientific methods and means of fitness and exercise for older men. At the same time, older men should be given enough sports guidance to make their physical exercise scientific and standardized, which will also reduce the occurrence of injury and accidents. Second, according to Zhou et al. (36) and research on the current state of physical exercise for older adults in Fujian Province, it is recommended to focus on and strengthen the organization and management of physical exercise for older adults through community participation. Meanwhile, communities should actively add diversified physical education courses for the older population to promote the richness of sports programs and improve the quality of life of older adults (37). Local communities should also fully make use of available opportunities in organizing, managing, and promoting sports activities for older men within their jurisdictions and promote the continuous enrichment of sports programs for older men. Third, in the construction of community sports and fitness facilities, certain human, material, and financial resources should be earmarked for sports facilities for older men, and the provision of sports venues and equipment for older men should be increased to create a better environment and conditions for older men to exercise. Strengthening sports services for older men can improve their quality of life. In addition to the above analysis of the quality of life and physical exercise of older men, it can be concluded that an important reason for the poor quality of life of older men is the serious lack of physical activity behavior of older men. This study highlights the importance of scientific and reasonable exercise for older men in promoting healthy aging. To fully maximize the benefits of physical exercise, a collaborative implementation path involving the government, society, and individuals is necessary. By working together, we can truly maximize the potential of physical exercise as a catalyst for healthy aging.

5. Conclusion

Our study had the following key observations: (1) The health of older men who lack physical exercise is poor. From the perspective of healthy aging, older men are a vulnerable group that deserves more attention; (2) Within reasonable limits, the more older men participate in physical activity programs, the more conducive they would be to improved health; and (3) This study focused on promoting physical exercise and healthy aging for older adults in China; organizing sports activities for older men is an important measure in promoting healthy aging.

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

Formal analysis, writing, data curation, and editing: MC and SC. Original draft preparation: YW and DS. Investigation: MC and LX. Revised the manuscript: MC, SC, YW, DS, LX, YS, and ZC. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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

Publisher's note

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Impact of adapted taekwondo vs. multicomponent training on health status in independent older women: a randomized controlled trial

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This study, called the TKD and Aging Project, aimed to analyze and compare the effects of an adapted taekwondo program concerning multicomponent training on blood pressure, morphological variables, food consumption frequency, health-related quality of life (HRQoL), physical fitness, handgrip strength, and postural balance in independent older women. A randomized controlled trial study was conducted with parallel groups for 8 weeks (24 sessions of 60 min each), employing a double-blind design and incorporating repeated measures. Twenty-eight older women initially participated in the intervention. Three participants were excluded because they did not participate in the re-assessments. Thus, 14 older women from the adapted taekwondo group (TKD; age: 62.86 ± 2.38 years) and 11 from the multicomponent training group (MCT; age: 63.18 ± 1.94 years) participated in the final analysis. A two-factor mixed analysis of variance (ANOVA) model with repeated measures was performed to measure the time × group effect. The TKD showed significant improvements in the mental health ($p = 0.024$; ES = 0.91) and general health ($p < 0.001$; ES = 0.75) dimensions of the HRQoL, as well as in the chair stand ($p = 0.001$; ES = 1.18), arm curl ($p < 0.001$; ES = 2.10), 2-min step ($p < 0.001$; ES = 1.73), and chair sit-and-reach ($p = 0.001$; ES = 0.91) tests. Additionally, it showed a significant reduction in postural balance for the eyes-closed condition in the center of the pressure area ($p = 0.021$; ES = 0.89), mean velocity ($p = 0.004$; ES = 0.79), and mediolateral velocity ($p < 0.001$; ES = 1.26). However, the MCT showed significant increases in the general health ($p = 0.013$; ES = 0.95) dimension of the HRQoL and a significant reduction ($p = 0.039$; ES = 0.28) in the mediolateral velocity of postural balance for the eyes-closed condition. Multiple comparisons showed that the TKD scored significantly higher in the chair stand ($p = 0.017$; ES = 1.79), arm curl ($p = 0.003$; ES = 1.77), and 2-min step ($p = 0.018$; ES = 0.91) tests than the MCT. Compared to multicomponent training, taekwondo improves postural balance and provides better benefits in terms of physical fitness and HRQoL for older women. Therefore, it is possible to recommend it as a safe physical activity strategy, as long as it is well-dosed, since it showed high adherence to intervention in older women.

KEYWORDS

combat sports, resistance training, exercise, older adults, healthy aging, aging

1. Introduction

Combat sports are considered risky physical activity due to their high injury rates in elite athletes (1, 2). For example, in Olympic combat sports athletes, the most frequent injuries and illnesses were 45.8% head/face injuries and bruises in boxing, 10.9% low back injuries in judo, 22.8% finger sprains in taekwondo, and 24.8% knee sprains in wrestling (1). Despite the aforementioned risks, combat sports are a prevalent physical activity practice (3). In addition, it has been suggested that, with appropriate dosage (e.g., selection of technical foundations, number of sessions and time, volume, intensity, and density), they can be used to train adults (4) and older people (5, 6), achieving benefits similar to other physical activity strategies at the physical, physiological, and psychoemotional levels. Recent systematic reviews (7, 8) have not been able to establish conclusive results regarding the favorable effects of Olympic combat sports on the health status of older people. However, the individual results of the studies analyzed indicate a significant reduction in fall risk (8) and an improvement in health-related quality of life (HRQoL) (7), with a mean adherence that is more significant than 80%.

In particular, adapted taekwondo interventions for older women have reported a significant increase in the number of repetitions of the chair stand (9, 10) and arm curl tests (10), as well as higher performance in the handgrip strength (HGS) (9, 11), and chair sit-and-reach tests (10). In addition, a significant reduction in systolic and diastolic blood pressure (9), a decrease in the seconds in the timed up-and-go (TUG) test (9, 10), significant improvements in brain-derived neurotrophic factor (10), and a substantial decrease in resting epinephrine (11) have also been reported to improve the HRQoL in healthy older women (10), hypertensive older women (11), and those with depression (9).

However, multicomponent training, which involves at least three essential physical qualities or abilities, typically resistance, aerobic capacity, balance, and flexibility (12, 13), has broad support and diffusion as a safe and effective physical activity intervention strategy for older people (12). Among the main benefits reported in an umbrella review of systematic reviews (12) were significant improvements in muscle strength, mobility, gait, balance, and general physical performance in community-dwelling frail older people. However, the review mentioned above indicated that there is still uncertainty about the most appropriate physical activity characteristics (type, frequency, intensity, duration, and combinations) for achieving the most beneficial and sustainable results over the long term (12).

Considering all of the above, it seems that both adapted taekwondo and multicomponent training achieve similar results concerning the general health status of older people (4, 6, 8, 12). Additionally, in Chile, older women are more sedentary, and the prevalence of being overweight/obese is higher among them than among men (14). According to the data available, this negatively affects the health status of Chilean older women (15), thereby justifying the promotion of novel physical activity strategies to encourage regular practice in this population group. In this sense, the present study aimed to analyze and compare the effects of an adapted taekwondo program concerning multicomponent training on blood pressure, morphological variables, food consumption frequency, HRQoL, physical fitness, HGS, and postural balance in independent older women. Based on previous systematic reviews (6–8, 12, 16), we hypothesized that adapted taekwondo would produce significantly greater effects on HRQoL and postural balance than a multicomponent training.

2. Materials and methods

2.1. Study design

This study design included a randomized controlled trial with parallel groups (adapted taekwondo group: TKD; multicomponent training group: MCT), repeated measures, and double-blinding of both participants and assessors. A research randomizer website (https://www.randomizer.org) was used for randomization. The CONSORT guidelines (17) and a study protocol from the TKD and Aging Project (18) were used as the methodology. In addition, the study was registered in the Clinical Trial Protocol Registry and Results System (ClinicalTrials.gov) of the United States of America (Code: NCT05275140; http://clinicaltrials.gov/search?cond=NCT05275140, accessed on July 14, 2023). The interventions were conducted over the course of 8 weeks, comprising a total of 24 sessions. These sessions occurred three times a week, lasting 60 min each, specifically on Mondays, Wednesdays, and Fridays. Blood pressure, morphological variables, food consumption frequency, HRQoL, physical fitness, HGS, and postural balance were all assessed. All measurements were taken in the afternoon—between 14:00 and 15:00 h—and in the same location (sports center), with the control of variables, including temperature, and the researchers who conducted the pre- and post-assessments. The older women had no musculoskeletal and/or cardiorespiratory injuries during the intervention, and they exhibited no pain prior to the assessments or during the training sessions. The summarized inclusion criteria are described in Figure 1.

2.2. Participants

Twenty-eight older women initially participated in the intervention. The sample size calculation indicated that the ideal number of participants per group is 16. Based on previous studies (19), for this calculation, an average difference of 3.46 repetitions (chair stand test) was used as the minimum difference required for substantial clinical relevance, with a standard deviation of 3.38 repetitions, considering an alpha level of 0.05 with 90% power and an expected loss of 15%. GPower software (Version 3.1.9.6, Franz Faul, Universiät Kiel, Kiel, Germany) was used to calculate the statistical power. The inclusion criteria were as follows: (*i*) older women aged between 60 and 65 years; (*ii*) those presenting the ability to understand and follow instructions in a contextualized manner through simple commands; (*iii*) those who were independent, which was defined as having a score of at least 43 points on the Preventive Medicine Exam for the Older People of the Chilean Ministry of Health (20); and (*iv*) those with the ability to adhere to the requirement of at least 85% attendance at the scheduled sessions for intervention. Regarding the exclusion

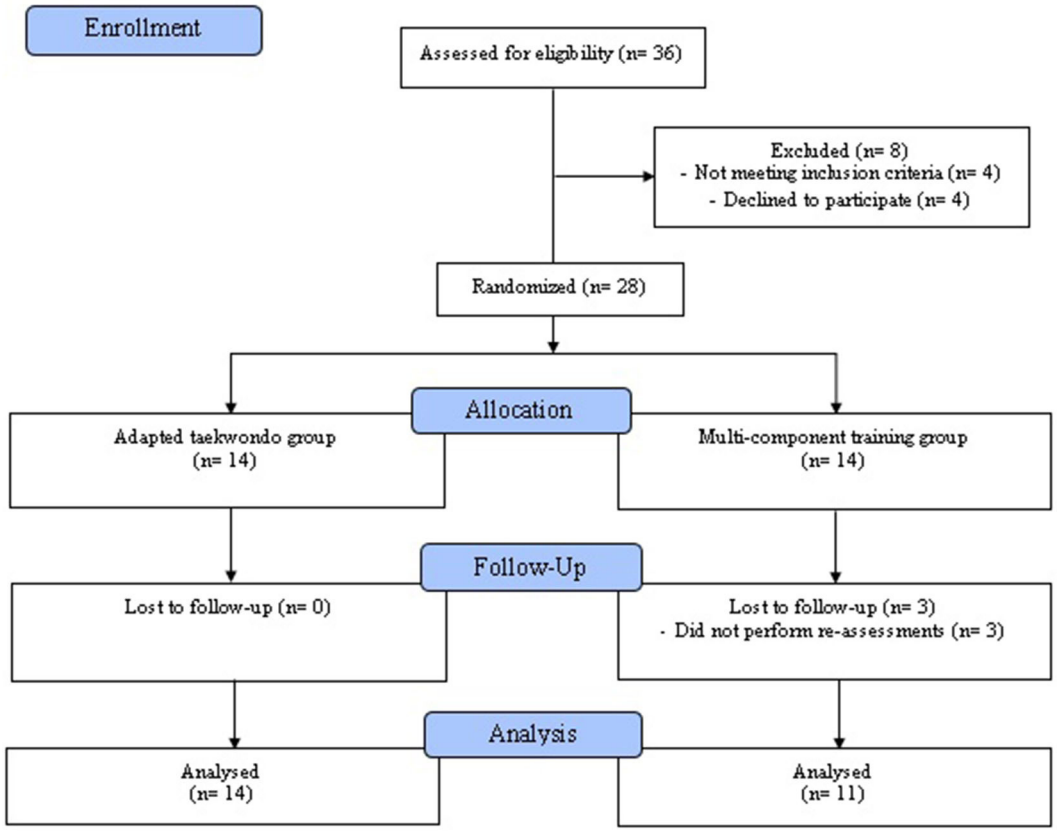

FIGURE 1
Study flowchart of the enrolment process, allocation, follow-up, and analysis of independent older women.

criteria, the following were considered: (*i*) having any disability condition; (*ii*) having musculoskeletal injuries or being treated for physical rehabilitation that prohibits them from doing their usual physical activities; and (*iii*) being unable to engage in physical activity either permanently or temporarily. Participants who met the inclusion criteria additionally had to attend all assessment sessions and finish at least 85% of the training sessions to be included in the final analyses. Three out of 28 older women considered for inclusion in the study were excluded because they did not participate in the re-assessments. Thus, 14 older women in the TKD (bipedal height: 1.55 ± 0.04 m) and 11 in the MCT (bipedal height: 1.54 ± 0.06 m) were analyzed.

All participants accepted the inclusion criteria for the usage and handling of the data by signing an informed consent form authorizing the use of the information for scientific purposes. The protocol was approved by the scientific ethics committee of the Universidad Católica del Maule, Chile (Number: N°29-2022) and was developed following the Declaration of Helsinki.

2.3. Primary outcomes

2.3.1. Blood pressure

An automatic pressure monitor (08A, CONTEC, Germany) was purchased to measure the systolic and diastolic blood pressure. Following bladder emptying, the older women were assessed after at least 10 min of prior rest in a seated position with the back, arms, and legs uncrossed. The first assessment was taken in both arms to identify the arm with the highest blood pressure. The arm with the highest blood pressure (typically the dominant arm) was then subjected to two assessments, and a third evaluation was also conducted if the difference between the results was >5 mmHg. Procedures to measure blood pressure were carried out as proposed by Reddy et al. (21).

2.3.2. Morphological variables

A digital scale (Seca 769, Germany; accuracy of 0.1 kg) was used for measuring body weight, and a stadiometer (Seca 220, Germany; accuracy of 0.1 cm) was used for measuring bipedal height. In accordance with the International Society for the Advancement of Kinanthropometry (ISAK) guidelines, all assessments were carried out by a level-II anthropometrist certified by the ISAK (22). The body mass index (BMI) of each older woman was also calculated by dividing weight in kilograms by the square of bipedal height in meters. To calculate the proportion of fat mass and fat-free mass, an eight-electrode tetrapolar bioimpedance device (InBody 570®, Body Composition Analyzers, Seoul, Korea) was used.

2.3.3. Food consumption frequency

A modified version of an eating habits survey for older people was used to measure the food consumption frequency; this survey was validated by employing the Delphi method based on the opinions of 25 nutrition experts (23). Furthermore, the survey was designed with two self-application areas. (*i*) The first area comprises 12 questions with a minimum score of 1 and a maximum score of 5 (Likert scale), reflecting the frequency of healthy foods, including that of advised food groups. The scale ranges from not consuming (1 point) to the recommended day/week servings (5 points), with a score of the responses ranging from 12 to 60 points (a higher value indicates better eating habits) (23). (*ii*) The second area comprises 7 items related to unhealthy foods or food groups identified as promoters of chronic non-communicable diseases (sugary drinks, alcohol, fried foods, fast food, sweet snacks, and coffee). Six of the questions have the same score as that of the previous one (1, does not consume, to 5, over three servings per day/week), and one is rated from 1 to 3 (salt), reaching a value ranging from 7 to 33 points (higher values indicate unhealthy food choices). Bad eating habit, such as adding salt to meals without tasting them, was added (23).

2.3.4. Health-related quality of life

This questionnaire was obtained using the Health Survey Short Form (SF-36) Version 2. It measures the attributes of eight health dimensions (24): physical function, physical role, body pain, general health, vitality, social function, emotional role, and mental health. Questions of each dimension are added together to form a scale, with the poorest health status for that dimension at 0 and the best health status at 100 (24).

2.3.5. Physical fitness

Physical fitness was evaluated by conducting the Senior Fitness Test, which offers an assessment of outstanding reliability and simple application (25). The chair stand test was conducted as the first assessment in the battery to determine the lower limbs' muscle strength by counting how many repetitions were completed in 30 s. The arm curl test measured the upper limbs' muscle strength by counting the number of repetitions completed in 30 s while holding a 3-lb dumbbell. A 2-min step test was conducted to measure cardiorespiratory fitness by counting the number of knee raises each participant accomplished, reaching at least a 70-degree angle at their hip joint. The lower limbs' degree of flexibility was measured in centimeters during the chair sit-and-reach test. The back scratch test was conducted to measure the upper limbs' degree of flexibility in centimeters. The TUG test was conducted to measure agility and dynamic balance by encircling a cone at a distance of 8 ft (2.44 m) while controlling time in seconds.

2.3.6. Handgrip strength

Using a hydraulic dynamometer (Camry, model EH101, China), HGS was measured in accordance with earlier recommendations (26). Older women were seated with their shoulders abducted, elbows flexed at 90° to one side of their bodies, forearms aligned neutrally, and wrists kept in a neutral position. The size of the hand was considered when adjusting the dynamometer, allowing for a functional and comfortable grip on the instrument with an adequate closure of the interphalangeal and metacarpal joints in the position of the fist, favoring contact between the first phalanges of the index and thumb. For each hand, three trials were made using the highest value possible in the three registers.

2.3.7. Postural balance

Using a force platform (ArtOficio Ltd., Valparaíso, Chile), the center of the displacement of pressure was measured in accordance with earlier recommendations (27). The data were acquired with a sampling rate of 40 Hz. Postural balance was assessed both with the eyes open and closed, and each assessment lasted 30 s. The older women were instructed to remain as still as possible in the bipedal position, with their arms at their sides and their feet aligned approximately shoulder-width apart. Using the Matlab r2012a program (Mathworks Inc., Natick, USA), the area and velocity variables of the center of pressure were calculated.

2.4. Secondary outcomes

Baseline assessments of age (years), academic level (primary, secondary, bachelor, or postgraduate), civil status (married, separated, widowed, single, or others), and smoking status (yes or no) were made.

2.5. Intervention

The study protocol explained the TKD and MCT programs in detail (18). The general structure of the programs included a 10-min warm-up comprising joint mobility and low-intensity aerobic exercises, followed by a 40-min central part (TKD or MCT) and concluding with a 10-min cooldown through dynamic and static flexibility exercises over 8 weeks (24 sessions). A summary of the intervention dosage is presented in Table 1. The Polar Team app version 1.3 (Polar Electro Oy, Kempele, Finland) was used to continuously monitor the older women. The intensity of the interventions remained moderate to vigorous, with each older woman's maximum heart rate (HRmax) used as a control (between 50 and 70% of HRmax). This was carried out with a heart rate sensor strap (H10, Polar Electro Oy, Kempele, Finland), which was live-transmitted via bluetooth to a tablet (iPad 4, Apple, Inc., Cupertino, CA, USA). The sessions were led by master's degree students in physical activity sciences, who have worked with older people, and a National Sports Federation of Taekwondo WT-certified taekwondo instructor (for TKD).

The central part of the TKD program comprised non-contact exercises, which were broken up into 10 min of basic postures and specific technical foundations for the upper limbs (strikes and blocks) and 20 min of technical foundations for the lower limbs (displacement, postures, and kicks). These exercises were performed individually and in pairs, with and without the use of taekwondo implements (impact pads and shields). In addition, participants practiced these modality-specific choreographies or

TABLE 1 Intervention dosage.

Program	Weeks	Fr (weekly)	TPS (min)	PE	Set	Rep	Rest	Intensity
TKD	1–4	3	60	ULs	3	8	2-min	50–70% HRmax
				LLs				
				Forms	—	6		
	5–8			ULs	4	8		
				LLs				
				Forms	—	6		
MCT	1–4		60	RT	3	10	2-min	OMNI-RES (5–8 points)
				CF				50–70% HRmax
				APC				
	5–8			RT	4	10		OMNI-RES (5–8 points)
				CF				50–70% HRmax
				APC				

APC, Agility and postural control; CF, Cardiorespiratory fitness; Fr, Frequency; HRmax, Maximum heart rate; LL, Lower limbs; MCT, Multicomponent training group; OMNI-RES, OMNI-Resistance Exercise Scale of perceived exertion; PE, Physical exercise; Rep., Repetitions; RT, Resistance training; TKD, Adapted taekwondo group; TPS, Total time per session; ULs, Upper limbs.

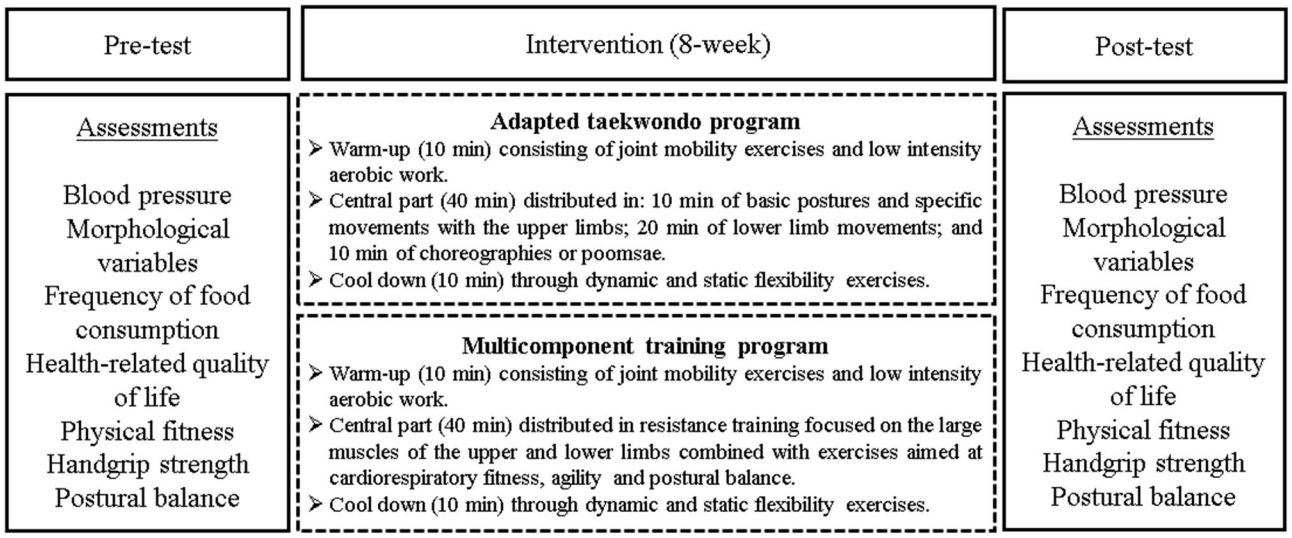

FIGURE 2
Assessments and regular sessions of the intervention.

poomsae for 10 min. The amount of training was measured in sets and repetitions of the specific technical foundations, with a 2-min rest in between sets. Perceived exertion was measured using the Borg scale, which has a maximum rating value of 10 points (28).

The central part of the MCT program was a 40-min circuit of distributed work that included exercises for cardiorespiratory fitness, agility, and postural balance using elastic bands, poles, 2-kg medicine balls, and chairs. The exercises targeted the biceps, triceps, deltoids, latissimus dorsi, quadriceps, hamstrings, glutes, and gastrocnemius, which correspond to the large muscles of the upper and lower limbs. The first training volume (the first 4 weeks) consisted of three sets of 10 repetitions of each muscle activity, with a 2-min rest in between sets. Slow movements, lasting 2 s for concentric and 4 s for eccentric contractions, were used. The volume was increased to four sets of 10 repetitions of each muscular exercise with a 2-min rest in between sets (between weeks 5 and 8). The OMNI-Resistance Exercise Scale of perceived exertion was used to control the resistance training intensity, which ranged from moderate to vigorous (5–8 points) (29). The assessments and regular intervention sessions are summarized in Figure 2.

2.6. Statistical analysis

The analysis was conducted using the statistical program GraphPad Prism 9 (GraphPad Software, Inc., La Jolla, CA, USA).

The mean and standard deviations were used to present the data. The analyzed outcomes complied with the normality of data through the Shapiro–Wilk test. Subsequently, a two-factor mixed analysis of variance (ANOVA) model with repeated measures was employed to measure the time × group effect of all the variables. A Bonferroni multiple comparison test (*post-hoc*) was conducted to determine the intra-group (pre vs. post) and inter-group (TKD vs. MCT) differences when the time × group interaction was significant. To determine the effect size of the time × group interaction, the partial eta square (ηp^2) was calculated, which was interpreted considering the ηp^2 values of 0.01, 0.06, and 0.14, which correspond to small, moderate, and large effect sizes (ES), respectively (30). For multiple comparisons, the ES was calculated using Cohen's d, considering a small ($\geq$0.2), moderate ($\geq$0.5), or large ($\geq$0.8) effect (31) size. A significant difference was established for all analyses at 5%.

3. Results

The mixed ANOVA revealed significant time × group interactions for the mental health ($F_{1,23} = 6.47$; $p = 0.038$; and $\eta p^2 = 0.22$) and general health ($F_{1,23} = 15.81$; $p = 0.002$; and $\eta p^2 = 0.20$) dimensions of HRQoL (Table 2). For blood pressure, morphological variables, food consumption frequency, and other dimensions of HRQoL, no significant time × group interactions were found (Table 2). Table 3 shows the results of the time × group interactions of physical fitness, HGS, and postural balance. Regarding physical fitness, significant interactions were revealed in the chair stand ($F_{1,23} = 6.43$; $p = 0.038$; and $\eta p^2 = 0.19$), arm curl ($F_{1,23} = 13.55$; $p = 0.007$; and $\eta p^2 = 0.36$), 2-min step ($F_{1,23} = 6.34$; $p = 0.039$; and $\eta p^2 = 0.36$), and chair sit-and-reach ($F_{1,23} = 9.07$; $p = 0.019$; and $\eta p^2 = 0.28$) tests. Similarly, significant interactions were only exhibited in postural balance for the eyes-closed condition in the center of the pressure area ($F_{1,23} = 5.29$; $p = 0.033$; and $\eta p^2 = 0.07$), mean velocity ($F_{1,23} = 6.19$; $p = 0.041$; and $\eta p^2 = 0.21$), and mediolateral velocity ($F_{1,23} = 5.66$; $p = 0.040$; and $\eta p^2 = 0.17$). There were no time × group interactions in HGS and other variables of postural balance.

The *post-hoc* analyses showed that, in the TKD, there were significant improvements in the assessments of the mental health ($p = 0.024$; ES = 0.91) and general health ($p < 0.001$; ES = 0.75) dimensions of HRQoL, while in the MCT, there were significant improvements in the general health dimension ($p = 0.013$; ES = 0.95) of HRQoL (Figure 3). Intergroup comparisons showed no significant differences.

However, in the TKD, physical fitness tests showed significant improvements in the performance of the chair stand ($p = 0.001$; ES = 1.18), arm curl ($p < 0.001$; ES = 2.10), 2-min step ($p < 0.001$; ES = 1.73), and chair sit-and-reach ($p = 0.001$; ES = 0.91) tests (Figure 4). Multiple comparisons revealed no significant pre- and post-intervention differences in the MCT. For the chair stand ($p = 0.017$; ES = 1.79), arm curl ($p = 0.003$; ES = 1.77), and 2-min step ($p = 0.018$; ES = 0.91) tests, significant differences were observed between the groups in the post-intervention assessment, favoring the TKD group.

Finally, in the TKD, multiple comparisons revealed a significant reduction in postural balance for the eyes-closed condition in the center of the pressure area ($p = 0.021$; ES = 0.89), mean velocity ($p = 0.004$; ES = 0.79), and mediolateral velocity ($p < 0.001$; ES = 1.26). In the MCT, the mediolateral velocity of postural balance for the eyes-closed condition significantly reduced ($p = 0.039$; ES = 0.28) (Figure 5). Intergroup comparisons showed no significant differences.

The baseline secondary outcomes revealed that, in general, the independent older women analyzed in this study had a mean age of 63.00 ± 2.16 years. Furthermore, 56% of them had a primary academic level, 36% had a secondary academic level, and 8% had a bachelor's or postgraduate degree. Additionally, it can be noted that 76% were married, 16% were separated, and 8% were widowed. Finally, 92% did not smoke (Table 4).

4. Discussion

This study aimed to analyze and compare the effects of an adapted taekwondo program comprising multicomponent training on blood pressure, morphological variables, food consumption frequency, HRQoL, physical fitness, HGS, and postural balance in independent older women. The primary outcomes indicated the following: (*i*) The TKD obtained significantly higher post-intervention results in the chair stand, arm curl and 2-min step tests than the MCT; (*ii*) the TKD significantly increased the mental health and general health dimensions of HRQoL and significantly improved performance in the chair stand, arm curl, 2-min step, and chair sit-and-reach tests of physical fitness, in addition to achieving significant improvements in postural balance for the eyes-closed condition in the center of the pressure area, mean velocity, and mediolateral velocity; (*iii*) the MCT significantly increased the general health dimension of HRQoL and improved postural balance for the eyes-closed condition in mediolateral velocity; and (*iv*) there are no significant changes in the TKD and MCT for blood pressure, morphological variables, food consumption frequency, HGS, back scratch test, and TUG, in six dimensions of HRQoL (physical function, role physical, body pain, vitality, social function, and role emotional) and postural balance for the eyes-open condition after 8 weeks of intervention. Based on our outcomes, the hypothesis was partially confirmed.

Blood pressure, morphological variables, and food consumption frequency did not present post-intervention changes in either the TKD or the MCT. Contrary to this finding, another previously adapted taekwondo intervention reported a significant reduction in body fat percentage, systolic blood pressure, and diastolic blood pressure in older women with depression when compared to an inactive control group (9). It has been reported that older people who participate in physical activity interventions enriched with nutrition education tend to select healthier food options than those who do not have such advice (32). Not finding beneficial changes in the mentioned variables with the TKD and MCT probably indicates the lack of nutritional advice. Nutritional education has been shown to have beneficial effects on food consumption frequency and body composition (33), while reducing the consumption of high-energy-density foods (foods rich in salt, sugar, and fat), such as ultra-processed foods. The reduction in high-energy-density foods' consumption can help reduce systolic and diastolic blood pressure in older

TABLE 2 Time × group interactions of blood pressure, morphological variables, food consumption frequency, and health-related quality of life in independent older women.

Variable	Assessment	Group	PRE		POST		Change (%)	*F*-value	*p*-value	ηp^2
			Mean	SD	Mean	SD				
Blood pressure	Systolic (mm/hg)	TKD ($n = 14$)	121.7	12.2	122.2	7.9	0.4	0.447	0.524	0.02
		MCT ($n = 11$)	133.0	17.2	137.0	14.1	3.0			
	Diastolic (mm/hg)	TKD ($n = 14$)	75.8	8.5	77.2	5.1	1.8	3.480	0.104	0.11
		MCT ($n = 11$)	77.7	9.6	85.3	8.4	9.7			
Morphological variables	Body weight (kg)	TKD ($n = 14$)	72.5	6.8	71.1	5.9	−1.9	2.696	0.144	0.09
		MCT ($n = 11$)	74.9	7.9	76.9	6.3	2.6			
	BMI (kg/m^2)	TKD ($n = 14$)	30.3	3.0	29.9	2.8	−1.3	4.311	0.076	0.13
		MCT ($n = 11$)	31.4	3.3	32.6	2.7	3.8			
	Fat mass (%)	TKD ($n = 14$)	29.5	6.0	29.2	4.8	−1.0	1.159	0.317	0.05
		MCT ($n = 11$)	32.0	6.8	33.4	4.7	4.3			
	Fat-free mass (%)	TKD ($n = 14$)	23.1	1.4	23.7	1.9	2.6	0.255	0.628	0.01
		MCT ($n = 11$)	22.9	2.5	23.8	1.9	3.9			
Food consumption frequency	Healthy food	TKD ($n = 14$)	37.4	4.8	36.0	11.1	−3.7	0.955	0.361	0.04
		MCT ($n = 11$)	41.8	4.6	43.3	4.9	3.5			
	Unhealthy food	TKD ($n = 14$)	13.3	4.2	10.8	2.5	−18.8	5.298	0.054	0.19
		MCT ($n = 11$)	11.8	2.4	12.7	3.0	7.6			
Health-related quality of life	PF (%)	TKD ($n = 14$)	76.0	16.4	81.44	14.7	7.1	0.083	0.780	0.02
		MCT ($n = 11$)	71.3	12.2	74.5	13.3	4.4			
	BP (%)	TKD ($n = 14$)	67.5	18.9	68.3	21.9	1.1	2.205	0.161	0.07
		MCT ($n = 11$)	67.9	25.6	83.84	13.9	23.4			
	RP (%)	TKD ($n = 14$)	94.6	20.0	100.0	0.0	5.7	0.001	0.999	0.03
		MCT ($n = 11$)	100.0	0.0	100.0	0.0	0.0			
	RE (%)	TKD ($n = 14$)	100.0	0.0	100.0	0.0	0.0	0.001	0.999	0.00
		MCT ($n = 11$)	100.0	0.0	100.0	0.0	0.0			
	MH (%)	TKD ($n = 14$)	56.2	17.3	71.44	16.0	27.1	6.472	**0.038***	0.22
		MCT ($n = 11$)	65.8	15.6	62.55	6.2	−4.9			
	SF (%)	TKD ($n = 14$)	72.3	27.8	71.4	19.2	−1.2	0.003	0.849	0.00
		MCT ($n = 11$)	75.0	15.8	76.1	14.2	1.4			
	VT (%)	TKD ($n = 14$)	62.5	12.3	71.1	16.1	13.7	0.870	0.381	0.03
		MCT ($n = 11$)	60.9	14.8	62.2	9.5	2.1			
	GH (%)	TKD ($n = 14$)	51.4	20.2	66.73	20.8	29.8	15.810	**0.002****	0.20
		MCT ($n = 11$)	47.7	16.9	62.77	14.7	31.5			

SD, Standard deviation; TKD, Adapted taekwondo group; MCT, Multicomponent training group; PF, Physical function; RP, Role physical; BP, Bbody pain; VT, Vitality; SF, Social function; RE, Role emotional; MH, Mental health; GH, General health; ηp^2, Partial eta squared.

*$p < 0.05$.

**$p < 0.01$.

Bold values represent significant differences.

TABLE 3 Time × group interactions of the physical fitness, handgrip strength, and postural balance in independent older women.

Variable	Assessment	Group	PRE		POST		Change (%)	*F*-value	*p*-value	ηp^2
			Mean	SD	Mean	SD				
Physical fitness	Chair stand (Rep)	TKD ($n = 14$)	15.8	4.2	20.1	3.0	27.2	6.436	**0.038***	0.19
		MCT ($n = 11$)	14.7	3.4	15.3	2.3	4.0			
	Arm curl (Rep)	TKD ($n = 14$)	21.0	5.0	31.7	5.2	50.9	13.550	**0.007****	0.36
		MCT ($n = 11$)	21.2	4.9	24.2	3.0	14.1			
	2-min step (Rep)	TKD ($n = 14$)	96.1	14.5	115.7	6.9	20.4	6.339	**0.039***	0.36
		MCT ($n = 11$)	95.0	16.5	99.5	8.7	4.7			
	Chair sit-and-reach (cm)	TKD ($n = 14$)	1.5	5.3	6.0	4.6	300.0	9.072	**0.019***	0.28
		MCT ($n = 11$)	3.0	6.3	2.9	5.0	−3.3			
	Back scratch (cm)	TKD ($n = 14$)	−6.1	6.4	−2.5	3.8	−59.0	5.418	0.052	0.16
		MCT ($n = 11$)	−4.4	6.3	−5.1	5.2	15.9			
	Timed up-and-go (s)	TKD ($n = 14$)	5.2	0.4	5.1	0.7	−1.9	3.169	0.118	0.12
		MCT ($n = 11$)	5.5	0.9	5.9	0.8	7.2			
Handgrip strenght	Dominant hand (kg)	TKD ($n = 14$)	22.1	3.4	23.0	2.9	4.0	0.002	0.961	0.00
		MCT ($n = 11$)	22.2	3.6	23.1	3.1	4.0			
	Non-dominant hand (kg)	TKD ($n = 14$)	20.6	3.7	22.0	3.1	6.8	0.811	0.397	0.03
		MCT ($n = 11$)	23.0	3.6	23.3	2.3	1.3			
Postural balance	Area EO (cm^2)	TKD ($n = 14$)	33.8	26.2	14.8	13.4	−56.2	0.949	0.362	0.04
		MCT ($n = 11$)	35.7	23.5	22.7	21.1	−36.4			
	Mean velocity EO (cm/s)	TKD ($n = 14$)	2.5	0.2	2.3	0.1	−8.0	2.328	0.170	0.09
		MCT ($n = 11$)	2.4	0.1	2.3	0.1	−4.2			
	ML velocity EO (cm/s)	TKD ($n = 14$)	3.0	0.6	2.5	0.2	−16.7	0.125	0.724	0.00
		MCT ($n = 11$)	3.6	2.4	2.8	0.8	−22.2			
	AP velocity EO (cm/s)	TKD ($n = 14$)	5.8	1.9	4.2	1.2	−27.6	2.151	0.185	0.09
		MCT ($n = 11$)	5.3	1.1	4.6	1.5	−13.2			
	Area EC (cm^2)	TKD ($n = 14$)	38.1	26.8	18.6	15.7	−51.2	5.290	**0.033***	0.07
		MCT ($n = 11$)	37.8	33.0	23.0	20.7	−39.2			
	Mean velocity EC (cm/s)	TKD ($n = 14$)	2.7	0.5	2.4	0.2	−11.1	6.192	**0.041***	0.21
		MCT ($n = 11$)	2.4	0.1	2.4	0.1	0.0			
	ML velocity EC (cm/s)	TKD ($n = 14$)	2.9	0.4	2.5	0.2	−13.8	5.66	**0.040***	0.17
		MCT ($n = 11$)	2.7	0.4	2.6	0.3	−3.7			
	AP velocity EC (cm/s)	TKD ($n = 14$)	5.7	1.4	4.8	1.0	−15.8	1.251	0.300	0.05
		MCT ($n = 11$)	5.0	0.9	4.6	0.8	−8.0			

SD, Standard deviation; TKD, Adapted taekwondo group; MCT, Multicomponent training group; EO, Eyes opened; EC, Eyes closed; ML, Mediolateral; AP, Anteroposterior; ηp^2, Partial eta squared.

*$p < 0.05$.

**$p < 0.01$.

Bold values represent significant differences.

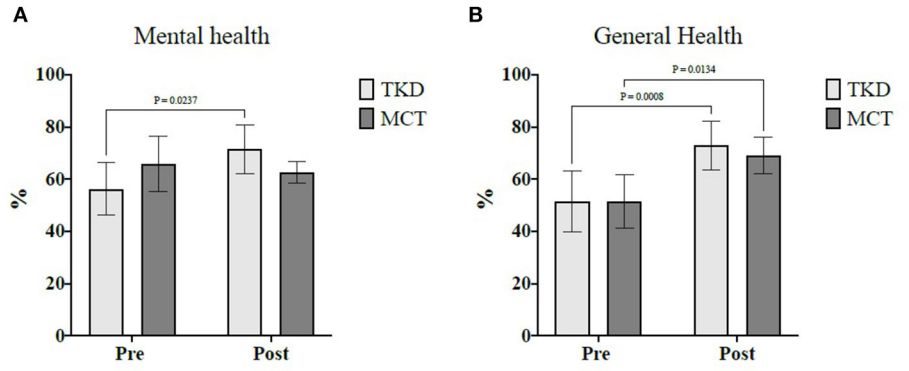

FIGURE 3
Multiple comparisons of health-related quality of life dimensions showed a significant time × group interaction in independent older women. **(A)** Mental health and **(B)** General health. TKD, Adapted taekwondo group; MCT, Multicomponent training group.

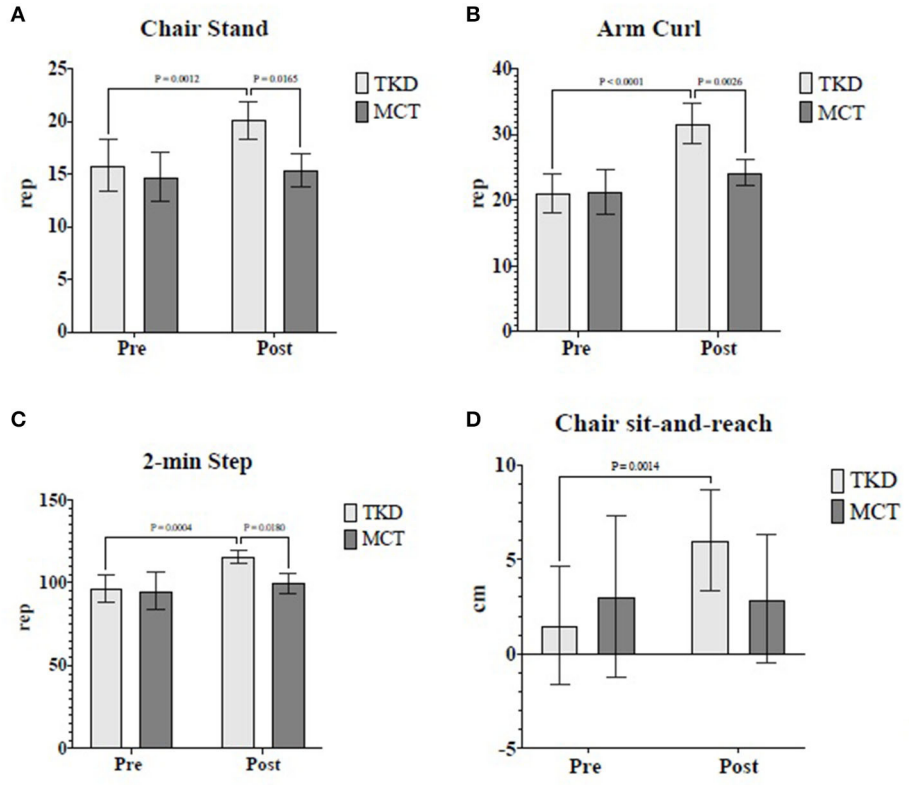

FIGURE 4
Multiple comparisons of physical fitness variables showed a significant time × group interaction in independent older women. **(A)** Chair stand, **(B)** Arm curl, **(C)** 2-min step, and **(D)** Chair sit-and-reach. TKD, Adapted taekwondo group; MCT, Multicomponent training group.

people (34). Therefore, an adapted combat sports strategy targeting older people seeking changes in morphological variables and food consumption frequency should incorporate nutritional education. This can generate changes in participants' lifestyles (32, 33), leading to a positive impact on systolic and diastolic blood pressure.

HRQoL did not reveal significant differences between the TKD and MCT. Nonetheless, although the participants presented favorable baseline values for most HRQoL dimensions, they showed improved mental health in the TKD and improved general health in both the TKD and MCT post-intervention. This observation is significant as it has been linked to poor morphological variables and physical fitness; for example, among the HRQoL dimensions, body mass, waist circumference, back scratch test, and TUG were significantly associated with low mental and general health in physically active older women (35). Furthermore, our findings are consistent with interventions based on Olympic combat sports (7) and multicomponent training (16), which have reported beneficial small-to-moderate ES on

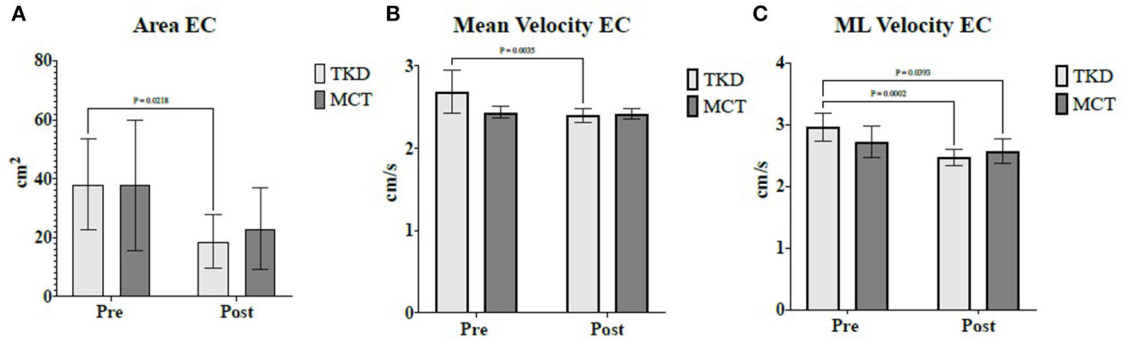

FIGURE 5
Multiple comparisons of postural balance variables showed a significant time × group interaction in independent older women. **(A)** Area eyes closed, **(B)** Mean velocity eyes closed, and **(C)** Mediolateral velocity eyes closed. TKD, Adapted taekwondo group; MCT, Multicomponent training group; EC, Eyes closed; ML, Mediolateral.

TABLE 4 **Baseline assessments of age, academic level, civil status, and smoking status of independent older women.**

Variable	Assessment	TKD ($n = 14$)	MCT ($n = 11$)	General sample ($n = 25$)
Age (years)*		62.86 ± 2.38	63.18 ± 1.94	63.00 ± 2.16
Academic level	Primary (%)	28	28	56
	Secondary (%)	24	12	36
	Bachelor (%)	4	0	4
	Postgraduate (%)	0	4	4
Civil status	Married (%)	48	28	76
	Separated (%)	8	8	16
	Widowed (%)	0	8	8
	Single (%)	0	0	0
	Others (%)	0	0	0
Smoking status	Yes (%)	4	4	8
	No (%)	52	40	92

*Data expressed as mean and standard deviation.
TKD, Adapted taekwondo group; MCT, Multicomponent training group.

HRQoL in middle-aged and older people. Older women are a vulnerable group facing the perception of HRQoL because they face more adverse and traumatic life events than older men, along with more frequent negative thoughts and intrusive memories than older men (36). Hence, participating in regular physical activity programs can help promote their general wellbeing (35).

Regarding physical fitness, significant differences were observed in favor of the TKD compared to the MCT in the post-intervention chair stand, arm curl, and 2-min step tests. Furthermore, the TKD demonstrated significant improvements in the results of the chair sit-and-reach test, but no significant changes were observed in the results of the back scratch test, TUG, and HGS. As for the MCT, it did not demonstrate significant changes in the physical fitness tests and HGS. Similar results were presented in previous studies that adapted taekwondo for older women; these studies reported substantial improvements in chair stand (9, 10), arm curl (10), and sit-and-reach (10) tests in favor of the taekwondo group. In addition, they found significant improvements in HGS (9, 11), which we did not detect in our study. However, previous studies (9–11) included control groups that continued their usual activities of daily living, unlike the present study that compared two training programs (TKD vs. MCT). Even though both groups (TKD and MCT) trained at the same intensity (50–70% of the HRmax), the TKD improved the results of the 2-min step test (related to cardiorespiratory fitness). This improvement was probably because of improvements in the chair stand test (related to the muscle strength of lower limbs). The improvements in the chair stand tests may have been due to the specificity of taekwondo's technical foundations, especially the knee raise achieved through hip flexion during kicks (which involve unipodal supports), which could also influence postural balance. In this sense, improving performance in tests related to muscle strength of the upper and lower limbs, cardiorespiratory fitness, and the flexibility of the lower limbs is associated with preventing or reducing sarcopenia (37) and achieving greater autonomy and independence in basic activities of daily living (16), which collectively favor active and healthy aging.

Although there were significant interactions in postural balance for the eyes-closed condition in the center of the pressure area, mean velocity, and mediolateral velocity, no significant differences between the TKD and MCT could be found. Nevertheless, both the TKD and MCT showed a substantial reduction in postural oscillations in the eyes-closed condition in mediolateral velocity. Furthermore, the TKD reduced postural instabilities, which was reflected in the decrease in the center of the pressure area and mean velocity. Similar to this finding, one study reported a significant improvement in postural balance in the eyes-open condition for both the adapted taekwondo and walking exercise groups compared to the passive control group, which was reflected in the decrease in the center of the pressure area, mean velocity, and mediolateral velocity (38). For its part, multicomponent training has been described as the best physical activity strategy to improve, among other variables, the rate of falls and balance performance in physically frail older adults (39). Carrying out interventions that lead to enhanced postural balance in older adults is crucial to decreasing fall risk in healthy older people because, during aging, there is a deterioration in static, dynamic, reactive, or multitasking balance (40), and falls are the second leading cause of death from unintentional injuries worldwide (41).

Some of the possible limitations of the study are as follows: (*i*) The lack of control and follow-up on food consumption, which could influence blood pressure, morphological variables, food consumption frequency, physical fitness, HGS, and postural balance in older women and (*ii*) the lack of an inactive control group to make a complete comparison between the training programs. Some of the main strengths of the study are as follows: (*i*) The comparison of two physically active groups (TKD vs. MCT) and the initial randomization of participants, which increased the study's internal consistency; (*ii*) the use of validated assessments that are widely used in scientific literature, which increased external validity, and (*iii*) the use of training programs tailored to the characteristics of older women, which reduced injury risk and increased adherence to interventions. Future studies could include men and women in the interventions to analyze the possible similarities or differences between the genders, in addition to including an inactive control group, which would help analyze the physical activity programs.

Finally, despite the statistical differences observed between the two groups (TKD and MCT) concerning the variables analyzed, the more effective intervention method for promoting health among older women may be related to intrinsic choices and participants' adherence to maintaining their participation in the intervention (42). Thus, in health promotion actions undertaken as part of municipal, state, or national interventions, it may be more advantageous to offer participants the freedom to choose the type of physical activity programs that best align with their preferences, thereby promoting increased adherence, satisfaction, and pleasure. Consequently, positive outcomes in terms of physical, nutritional, and psychological status can be expected, highlighting the importance of the principle of continuity of training for older people.

5. Conclusion

The multiple comparisons showed that the adapted taekwondo program achieved significantly higher results in the chair stand, arm curl, and 2-min step tests than multicomponent training in independent older women. In addition, the TKD offered beneficial and significant changes in mental health, the general health dimension of HRQoL, the chair sit-and-reach test, and postural balance for the eyes-closed condition, specifically in the area, mean velocity, and mediolateral velocity. In contrast, the MCT showed significant improvements in the general health dimension of HRQoL and postural balance for the eyes-closed condition, specifically, in mediolateral velocity. Compared to multicomponent training, taekwondo improves postural balance and achieves better benefits at physical fitness and HRQoL levels among older women. Therefore, it is possible to recommend taekwondo as a safe physical activity strategy, given its high adherence to intervention among older women when following the dosage and activities proposed in this study's program.

Data availability statement

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

Ethics statement

The studies involving humans were approved by the Scientific Ethics Committee of the Universidad Católica del Maule, Chile (Number: N°29-2022). 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

PV-B was responsible for conceptualizing the study. The methodology was developed by PV-B, EG-M, and TH-V. PV-B and EG-M were involved in the implementation of software. Formal analysis was conducted by PV-B, EG-M, and TH-V. The investigation involved the efforts of PV-B, EG-M, TH-V, BB, JH-M, and HN. PV-B prepared the initial draft and review and editing were performed by PV-B, EG-M, TH-V, BB, JH-M, and HN. PV-B, EG-M, and TH-V supervised the project. All authors have reviewed and approved the final version of the manuscript for publication.

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Conflict of interest

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

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A comparison of quality of life between older adults living in high and low altitude areas

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Background: High altitude is known to have a significant impact on human physiology and health, therefore, understanding its relationship with quality of life is an important research area. This study compared the quality of life (QOL) in older adults living in high and low altitude areas, and examined the independent correlates of QOL in those living in a high altitude area.

Methods: Older adults living in three public nursing homes in Xining (high altitude area) and one public nursing home in Guangzhou (low altitude area) were recruited. The WHOQOL-BREF was used to measure the QOL.

Results: 644 older adults (male: 39.1%) were included, with 207 living in high altitude and 437 living in low altitude areas. After controlling for the covariates, older adults living in the high altitude area had higher QOL in terms of physical ($P = 0.035$) and social domains ($P = 0.002$), but had lower QOL in psychological ($P = 0.009$) domain compared to their counterparts living in the low altitude area. For older adults living in the high altitude area, smoking status was associated with higher social QOL ($P = 0.021$), good financial status was associated with higher physical QOL ($P = 0.035$), and fair or good health status was associated with higher physical ($p < 0.001$) and psychological QOL ($P = 0.046$), while more severe depressive symptoms were associated with lower QOL.

Conclusion: Appropriate interventions and support to improve depressive symptoms and both financial and health status should be developed for older adults living in high altitude areas to improve their QOL.

KEYWORDS

older adults, high altitude, depression, quality of life, low altitude

Introduction

Quality of life (QOL) is a widely used health outcome with multiple dimensions that involve subjective sense of mental and physical status, social roles and functioning, personal relationships, and environmental factors (1). Among different age groups, QOL in older adults is a topic of concern (2). During the past decade, the research on QOL in older adults has mainly focused on its relationships with impairments of body function (3), physical and mental illnesses (4), cognitive deficits (5), and increased social and economic burden (6).

Previous studies found that unhealthy lifestyle factors (e.g., heavy smoking and drinking) were associated with lowered QOL (7–10) that was moderated by impaired physical (11, 12) and mental health status (13, 14). In addition, cognitive impairment was common among older adults living in high altitude areas, which was not associated with QOL in this population (5). In contrast, the influence of certain environmental factors on QOL is relatively less well-understood or studied. Living at high altitude has well-known impacts on health status due to hypobaric hypoxia in high-altitude areas for both local residents and those who recently arrived (15, 16). Some studies found that genetic factors in long-term high altitude residents could play a role in adapting to their local environment better than those living in other areas (17–21). Further, other studies examined the direct impact of high altitude on health including the influence of living in moderate altitude areas on the reproductive function (22), metabolic syndrome (23), and other cardiometabolic functions (24). Overall, acute mountain sickness is the most common discomfort experienced by newcomers to high altitude areas, which is associated with sleep problems and headache, dizziness, nausea and vomiting, sleep disturbance and fatigue (15). Chronic mountain sickness (CMS) that affects local residents in high altitude areas is related to a progressive loss of ventilatory rate, which naturally occurs with age and result in excessive hypoxemia and polycythemia (25). Some studies found that residents living in high altitude areas were more likely to suffer from high-altitude polycythemia (26), high-altitude pulmonary hypertension (27), congenital cardiac anomalies (28, 29), chronic kidney (30), and rheumatoid arthritis (31) due to hypoxia compared to those living in low altitude areas, all of which are negatively associated with QOL.

On the other hand, moderate altitude levels could have positive effects on sugar metabolism and blood pressure. For example, inhabitants living in the Valley of Mexico (2,240 m above sea level) were found to breathe 29% more on average and have 10% higher hemoglobin concentrations compared to residents living near sea level. Young adults in Mexico City had an SaO2 between 92 and 94% vs. 97% among those living at sea level (32). It is likely that lung growth, development during pregnancy and infancy, and other physiological adaptations are enhanced in moderate altitude levels, although solid evidence is still needed. However, for people with respiratory diseases, residing at moderate altitudes could result in worsening hypoxemia and clinical deterioration (32).

To date there have been no comparative studies on the influence of living in high altitude areas on QOL in older adults. This study hence compared the QOL in older adults living in high and low altitude areas and explored the correlates of QOL in those living in high altitude area.

Methods

Study design and participants

This was part of a cross-sectional, comparative study on mental health in older adults living in high and low altitude areas (33). The surveys were conducted from September 1st to November 31st in 2019 in three public nursing homes in Xining that is the capital city of Qinghai province with an average altitude of 2,300 m (high altitude area), and one public nursing home in Guangzhou which is the capital city of Guangdong province with an average altitude of 10 m (low altitude area). Older adults included in this study were living in the selected nursing homes, aged 60 years or above and able to understand the purpose and content of the assessment. Those with severe cognitive problems (e.g., dementia and severe head injury) as determined by a review of health records were excluded. The study protocol was approved by the Ethical Committee of the University of Macau. Written informed consent were provided by all participants.

Instruments

Basic sociodemographic and clinical characteristics, such as age, gender, marital status, education level, perceived financial and health status, and having a religion and major medical conditions, were collected in an interview and confirmed by a review of health records. QOL was measured using the validated Chinese version of the WHO Quality of Life brief version–WHOQOL-BREF (34, 35) that consists of 26 items covering four domains: physical, psychological, social relationships, and environment. Each item were scored from 1 to 5 points (36), with a higher score indicating higher QOL.

The validated Chinese version of the Patient Health Questionnaire (PHQ-9) (37, 38) was used to measure the severity of depression. The PHQ-9 consists of nine items with each scored from 0 = "not at all", 1 = "several days" to 2 = "more than half of the days" and 3 = "nearly every day". The PHQ-9 total score ranges from 0 to 27, with a higher score indicating more severe depression.

Data analyses

The sociodemographic and clinical characteristics of older adults living in the high and low altitude areas were compared using chi-square test, two independent samples *t*-test and Mann-Whitney *U*-test as appropriate. Then QOL between older adults living in the high and low altitude areas was compared using analysis of covariance (ANCOVA) after controlling for those that significantly differed in univariate analyses. The associations between socio-demographic and clinical characteristics and QOL in older adults living in high altitude area were examined using two independent samples *t*-test, analysis of variance, chi-square test, and Pearson correlation analysis. Finally, multiple linear regression analyses were used to analyze the independent correlates of QOL in older adults living in the high altitude area. Each of the physical, psychological, social relationships, and environmental QOL was the dependent variable, while demographic and clinical variables that significantly differed in univariate analyses were entered as the independent variables. IBM SPSS Statistics for Windows, version 24.0 (IBMCorp., Armonk, N.Y., USA) was used to analyze data. *P*-value was set at 0.05 (two-tailed).

Results

Altogether, 644 older adults were included, with 207 in high and 437 in low altitude areas who completed the assessment. There

TABLE 1 Basic demographic and clinical characteristics of the whole sample.

	The whole sample ($n = 644$)		Low altitude ($n = 437$)		High altitude ($n = 207$)		Statistics		
	N	%	*N*	%	*N*	%	X^2	*df*[a]	*P*
Gender							3.62	1	0.057
Female	**392**	**60.9**	**277**	**63.4**	**115**	**55.6**			
Male	252	39.1	160	36.6	92	44.4			
Married/cohabitating	136	21.1	87	19.9	49	23.7	1.19	1	0.275
Secondary school or above	274	42.6	198	45.3	76	36.7	4.24	1	**0.039**
Smoking	136	21.1	91	20.8	45	21.7	0.07	1	0.790
Having a religion	504	78.3	423	96.8	81	39.1	321.90		**<0.001**
Perception of financial status							31.31	2	**<0.001**
Good	256	39.8	144	32.9	112	54.1			
Fair	290	45.0	210	48.0	80	38.6			
Poor	98	15.2	83	19.0	15	7.2			
Perception of health status							24.62	2	**<0.001**
Good	154	23.9	84	19.2	70	33.8			
Fair	374	58.1	282	64.5	92	44.4			
Poor	116	18.0	71	16.2	45	21.7			
Presence of major medical conditions[d]	609	94.56	430	98.40	179	86.47	38.86	1	**<0.001**
	Mean	SD	Mean	SD	Mean	SD	T/Z	*df*[b]	*p*
Age (years)	80.4	8.6	81.5	8.3	78.12	8.8	4.65	642	**<0.001**
PHQ-9 total	3.0	3.9	1.6	2.8	6.02	4.1	−14.83	–[c]	**<0.001**
Physical QOL	13.2	2.0	13.1	1.8	13.2	2.3	0.385	642	0.700
Psychological QOL	13.5	2.1	13.6	1.9	13.3	2.3	2.061	642	**0.040**
Social QOL	13.4	1.8	13.4	1.5	13.6	2.4	1.210	642	0.227
Environmental QOL	13.4	1.9	13.4	1.8	13.2	2.2	1.052	642	0.293

df, degree of freedom; SD, standard deviation; PHQ-9, Patient Health Questionnaire-9; QOL, quality of life.
[a] χ^2 test.
[b] Two sample independent *t*-test.
[c] Mann-Whitney *U*-test.
[d] Major medical conditions including included Hypertension, Cardiopathy, Stroke, Parkinson, Diabetes, Asthma, Chronic bronchitis Emphysema, Pulmonary disease, Liver disease, Nephropathy, Thyroid dysfunction, Arthritis, Cancer, racture/Osteoporosis/Humpback, Other diseases.
Bolded values: $p < 0.05$.

were significant differences between older adults living high and low altitude areas in terms of age, education, religion, perception of financial status, perception of health status, number of major medical conditions, psychological QOL and PHQ-9 total score (Table 1). ANCOVA revealed that after controlling for variables that significantly differed in the univariate analyses, older adults living in high altitude area had significantly higher physical [$F_{(1,644)} = 4.46$, $P = 0.035$] and social QOL [$F_{(1,644)} = 9.30$, $P = 0.002$], and lower psychological QOL [$F_{(1,644)} = 6.94$, $P = 0.009$] compared to those living in low altitude area. There was no group difference in environmental [$F_{(1,644)} = 0.32$, $P = 0.570$] QOL.

Table 2 shows the associations between basic and clinical demographic characteristics and QOL domains in older adults living in high altitude areas. Male gender was significantly associated with physical and psychological QOL, while smoking status, perceived health status and depressive symptoms were associated with all four QOL domains. Perceived financial status, medical conditions and age were also associated with physical QOL.

Table 3 presents the results of multiple linear regression analyses in older adults living in high altitude areas. For older adults living in high altitude area, smoking status was associated with higher social QOL (β = 0.16, 95% CI: 0.14–1.74, $P = 0.021$), while good financial status was associated with higher physical QOL (β = 0.24, 95% CI: 0.08–2.16, $P = 0.035$), fair or good health status were associated with higher physical QOL (fair health status: β = 0.30, 95%CI: 0.71–2.09, $p < 0.001$; good health status: β = 0.54, 95%CI: 1.89–3.39, $p < 0.001$) and psychological QOL (β = 0.18, 95% CI: 0.02–1.68, $P = 0.046$), and more severe depressive symptoms were associated with lower physical (β = −0.19, 95% CI: −0.17 to −0.04, $P = 0.002$), psychological (β = −0.29, 95% CI: −0.23 to −0.08, $P < 0.001$), social (β = −0.26, 95% CI: −0.24 to

TABLE 2 Associations between socio-demographic characteristics and QOL domains in older adults in high altitude region.

	Physical QOL			Psychological QOL			Social QOL			Environmental QOL		
	Mean ± SD	T/F	*P*	Mean ± SD	T/F	P	Mean ± SD	T/F	*P*	Mean ± SD	T/F	*P*
Gender		2.20	**0.029**		2.18	0.030		0.59	0.556		0.64	0.522
Male	13.6 ± 2.5			13.7 ± 2.5			13.7 ± 2.5			13.4 ± 2.4		
Female	12.9 ± 2.0			13.0 ± 2.0			13.5 ± 2.4			13.2 ± 2.1		
Marital status		0.92	0.357		1.42	0.157		0.40	0.689		0.47	0.636
Single/devoiced/widow	13.1 ± 2.2			13.1 ± 2.2			13.5 ± 2.2			13.3 ± 2.1		
Married/cohabitating	13.4 ± 2.5			13.7 ± 2.5			13.7 ± 3.0			13.1 ± 2.6		
Education		0.24	0.807		0.77	0.444		0.75	0.455		0.47	0.637
Illiterate or primary school	13.1 ± 2.2			13.2 ± 2.2			13.5 ± 2.3			13.3 ± 2.0		
Secondary school or above	13.2 ± 2.5			13.4 ± 2.3			13.7 ± 2.6			13.1 ± 2.5		
Smoking		2.29	**0.023**		2.57	**0.011**		2.94	**0.004**		2.04	**0.043**
No	13.0 ± 2.1			13.1 ± 2.3			13.3 ± 2.3			13.1 ± 2.1		
Yes	13.9 ± 2.7			14.0 ± 2.1			14.5 ± 2.5			13.8 ± 2.4		
Having a religion		0.19	0.845		0.98	0.327		0.43	0.668		1.58	0.114
No	13.2 ± 2.2			13.4 ± 2.2			13.6 ± 2.3			13.4 ± 2.1		
Yes	13.1 ± 2.4			13.1 ± 2.3			13.5 ± 2.6			12.9 ± 2.3		
Perception of financial status		6.13	**0.003**		2.78	0.064		2.95	0.055		1.59	0.207
Good	13.7 ± 2.3[ab]			13.6 ± 2.4[b]			13.9 ± 2.4[b]			13.5 ± 2.5		
Fair	12.7 ± 2.1			12.8 ± 2.0			13.1 ± 2.2			12.9 ± 1.8		
Poor	12.0 ± 2.4			13.3 ± 1.3			13.5 ± 3.0			13.0 ± 1.7		
Perception of health status		32.89	**<0.001**		4.02	**0.019**		3.99	**0.020**		3.35	**0.037**
Good	14.6 ± 2.1[ab]			13.7 ± 2.4[a]			14.2 ± 2.5[ab]			13.7 ± 2.4[a]		
Fair	13.0 ± 2.0[a]			13.3 ± 2.2			13.4 ± 2.3			13.2 ± 2.1		
Poor	11.5 ± 1.7			12.5 ± 1.9			13.0 ± 2.4			12.6 ± 2.1		
Presence of major medical conditions		3.02	**0.003**		0.95	0.344		1.24	0.218		1.03	0.308
Good	14.4 ± 2.5			13.6 ± 2.2			14.1 ± 2.5			13.7 ± 2.4		
Poor	13.0 ± 2.2			13.2 ± 2.2			13.5 ± 2.4			13.2 ± 2.2		
	r_p		*P*	r_p		*P*	r_p		*P*	r_p		*P*
Age (years)	−0.17		**0.013**	−0.04		0.528	−0.01		0.910	−0.07		0.302
PHQ-9 total	−0.32		**<0.001**	−0.33		**<0.001**	−0.30		**<0.001**	−0.27		**<0.001**

SD, standard deviation; PHQ-9, Patient Health Questionnaire-9; QOL, quality of life; r_p, Pearson's Correlation coefficient; T, two sample independent *t*-test; F, analysis of variance.
[a]Compare with *Poor* group, $p < 0.05$.
[b]Compare with *Fair* group, $p < 0.05$.
Bolded values: $p < 0.05$.

−0.07, $P < 0.001$), and environmental QOL (β = −0.23, 95% CI: −0.20 to −0.05, $P = 0.001$).

Discussion

This was the first comparative study of older adults that examined the association between living at high altitude areas and QOL. We found that older adults living in high altitude area had higher physical and social QOL, but lower psychological QOL compared to their counterparts living in low altitude area. For older adults living in high altitude area, smoking status, perceived financial and health status, and depressive symptoms were associated with QOL.

Older adults living in high altitude area had lower psychological QOL than those living in low altitude area, which could be due to increased risk of psychological and psychiatric sequelae of residing in high altitude areas, such as sleep disturbances (33, 39), stress, depression, anxiety (40) and even suicide (41). This was partly supported by our study findings in that those with more

TABLE 3 Socio-demographic correlates of QOL in older adults living in high altitude region (by multiple linear regression analysis).

	Physical QOL			Psychological QOL			Social QOL			Environmental QOL		
	P	*β*	95%CI	*P*	*β*	95%CI	*P*	*β*	95%CI	*P*	*β*	95%CI
Male gender	0.472	0.04	−0.36 to 0.77	0.211	0.09	−0.23 to 1.02	0.584	−0.04	−0.86 to 0.49	0.665	−0.03	−0.77 to 0.50
Smoking	0.231	0.07	−0.03 to 1.07	0.082	0.12	−0.08 to 1.40	**0.021**	0.16	0.14–1.74	0.218	0.09	−0.28 to 1.23
Perception of financial status												
Fair	0.556	0.07	−0.75 to 1.39	0.182	−0.17	−1.99 to 0.38	0.166	−0.18	−2.19 to 0.38	0.510	−0.09	−1.61 to 0.80
Good	**0.035**	0.24	0.08–2.16	0.808	−0.03	−1.30 to 1.02	0.902	−0.02	−1.33 to 1.17	0.776	0.04	−1.01 to 1.35
Perception of health status												
Fair	**<0.001**	0.30	0.71–2.09	0.112	0.14	−0.15 to 1.38	0.490	0.06	−0.54 to 1.12	0.222	0.11	−0.30 to 1.26
good	**<0.001**	0.54	1.89–3.39	**0.046**	0.18	0.02–1.68	0.071	0.16	−0.07 to 1.73	0.089	0.16	−0.11 to 1.59
Presence of poor major medical conditions	0.421	−0.05	−1.12 to 0.47	0.984	0.01	−0.88 to 0.90	0.673	−0.03	−1.16 to 0.75	0.759	−0.02	−1.04 to 0.76
Age (years)	0.109	−0.10	−0.06 to 0.01	0.346	0.07	−0.02 to 0.05	0.276	0.08	−0.02to 0.06	0.854	−0.01	−0.04 to 0.03
PHQ-9 total	**0.002**	−0.19	−0.17 to −0.04	**<0.001**	−0.29	−0.23 to −0.08	**<0.001**	−0.26	−0.24 to −0.07	**0.001**	−0.23	−0.20 to −0.05

CI, confidence interval; PHQ-9, Patient Health Questionnaire-9; QOL, quality of life.
β refer to standard coefficient of multiple linear regression analysis.
Bolded values: $p < 0.05$.

severe depressive symptoms were more likely to have lower QOL. Moreover, high psychological stress could also contribute to poor physical health such as heart disease (42) and cancer (43), which in turn could further lower psychological QOL.

There are several possible reasons for the association between high altitude and increased risk of psychiatric symptoms. Living at high altitude is associated with hypobaric hypoxia, which could impair brain functions over time (44) and increase the likelihood of psychiatric comorbidities including depression (40). In addition, persons living at high altitude are exposed to chronic hypoxia, which could lead to a number of physical diseases, such as high-altitude polycythemia (26), high-altitude pulmonary hypertension (27), and congenital cardiac anomalies (28, 29). All these factors could increase the risk of mental health problems due to the respective burden of the disease and treatment which could lower QOL.

Unexpectedly, our study revealed that adults living in a high altitude area had higher QOL in both physical and social domains but no difference in environmental domain compared to their counterparts living in low altitude area. This could be explained by the following reasons. QOL is largely determined by the gap between one's expectation and actual experiences (45). In the past decade, the central Chinese government has allocated substantial budget and health resources to improve the health service systems and living conditions for the population living in Qinghai-Tibet Plateau, particularly cities such as Xining city where this study was conducted. Therefore, the participants' experiences in terms of physical, social and environmental aspects would be expected to improve, which would match or even exceed their earlier expectations. However, like most areas across China, the implementation of mental health promotion and services (e.g., the Psychological Care Project for Older Adults) were still under-developed in the community which might influence psychological QOL. In addition, environmental and social factors could play an important role on QOL (46). In developed areas such as in Guangzhou (low altitude area), crowded living, noise pollution, fast working pace, competitive pressure and stress of high living cost could negatively influence QOL; in contrast, these factors were less evident in economically under-developed area such as Xining (high altitude area), which might partly explain the finding that adults living in high altitude area had higher QOL in both physical and social domains.

Several sociodemographic and clinical characteristics were associated with QOL in this study. Smoking could increase the risk of a range of physical diseases (47–49), which in turn could lowered QOL (50, 51). However, surprisingly older adults who smoke had higher social QOL in this study. In traditional Chinese culture, smoking and drinking are common social behaviors used to enhance social networks, facilitate interpersonal interactions, increase social activity of older people to reduce loneliness (52–54), all of which could improve QOL. Consequently, compared to those who do not smoke, older adults who smoke usually have a better social network and supports (55, 56), which could improve QOL in the social domain. As expected, older adults with better perceived

financial and health status were more likely to have higher QOL. Better financial situation and health status are usually associated with greater level of health literacy and access to healthcare services (57, 58) as well as good social support (59) in older adults, all of which could improve QOL.

There are several limitations in this study. First, due to the cross-sectional study design, causal relationship between QOL and other variables could not be examined. Second, for logistical reasons, the participants were invited from nursing homes and those with obvious cognitive problems were excluded, which would limit the generalizability of the findings. Finally, some variables related to QOL, such as treatment of physical diseases, were not examined.

In conclusion, our study of older adults found a significant association between living at high altitude and QOL. Older adults living in a high altitude area had higher physical and social QOL, but lower psychological QOL. Appropriate interventions to address depressive symptoms (e.g., increase access to community mental health services), and support to improve financial and health status should be developed for older adults living in high altitude areas to improve their QOL.

Data availability statement

The datasets presented in this article are not readily available because the Clinical Research Ethics Committee of University of Macau that approved the study prohibits the authors from making publicly available the research dataset of clinical studies. Requests to access the datasets should be directed to xyutly@gmail.com.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethical Committee of the University of Macau. The patients/participants provided their written informed consent to participate in this study.

Author contributions

YF and Y-TX: study design. SL, FW, SS, HC, and Y-TX: collection, analyses, and interpretation of data. SL and Y-TX: drafting of the manuscript. CN: critical revision of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

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Protocol of the MOVI-ageing randomized controlled trial: a home-based e-Health intervention of cognitively demanding exercise for the improvement of cardiorespiratory fitness and cognitive function in older individuals

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Objective: To describe the protocol of the MOVI-ageing randomized controlled trial, a home-based eHealth intervention of cognitive-demanding exercise for older adults, in improving global cognitive function and basic cognitive functions, cardiorespiratory fitness, and muscle fitness.

Methods: This randomized controlled trial will include participants identified in the social centers of Cuenca and Talavera de la Reina who agree to participate and provide informed consent. Adults aged 60–80 years of both genders retired regardless of the reason for retirement, who do not meet frailty criteria according to Fried criteria, and without cognitive impairment will be invited to participate. This study will be developed in two phases: (i) a 12-week randomized efficacy/feasibility trial and (ii) a large-scale implementation randomized trial phase with a 12-week follow-up following similar procedures. In addition, a qualitative study on barriers to and facilitators of the implementation of the physical exercise intervention using eHealth for older people will be conducted. Participants will have access to a platform including videos of cognitively demanding physical exercise. The participants will be remotely and off-line guided through the physical exercise intervention, and the research team will be able to check the degree of compliance with the program and its correct execution. The participants will receive feedback on their compliance with the routines and reinforcement messages.

Implications: The implementations of the findings and their inclusion in guidelines may directly impact in older people's life, and relatives, through the prevention of morbidity and the reduction of years lost to disability. These benefits may be reflected in the reduction of economic expenditure by reducing the demand for social and health care services.

Ethics: The Clinical Research Ethics Committee of the 'Virgen de la Luz' Hospital in Cuenca approved the study protocol (registration number: 2022/PI3222). In addition, this protocol was previously registered in Clinicaltrials.gov (Number: NCT05928078).

KEYWORDS

ageing, clinical trial, epidemiology, patient-centered care, primary prevention, sports medicine

Introduction

Although there is significant heterogeneity in the aging process, it is accompanied by a general decline in functional capacity, mainly related to the process of sarcopenia and to oxidative and inflammatory processes associated with arterial aging (1, 2). Age-related physiological and pathological changes and the complications arising from them have a major impact on lifestyle (1). Good muscle capacity is essential for the maintenance of functional ability and the promotion of quality of life (QoL). Aging-related declines in strength and respiratory capacity are well-known causes of decreased walking speed and increased mobility limitations and disabilities among older individuals, all of which are risk factors for institutionalization and mortality (3). In addition, declining health is associated with functional limitations, restricted social interaction, and impaired mental health status, including reduced cognitive function, neurodegeneration, and the development of dementia (1).

Moreover, cognitive impairment is one of the most common causes of disability in developed countries among the older adults (4). Cognitive decline and dementia place social and economic pressure on the governments of nations, which is expected to increase as a new case of dementia is diagnosed every 4 s (5–7). This means that approximately 115 million older people worldwide are likely to suffer from Alzheimer's disease/dementia by 2050. Although the economic costs are enormous, the combined economic and social burden of dementia is even more daunting, as it corresponds to the burden of people with dementia and their families and is, therefore, difficult to calculate (8). In view of this situation, the World Health Organization (WHO) emphasizes the importance of taking comprehensive actions against cognitive impairment and dementia and urges governments and institutions to develop prevention strategies that reduce the risk of cognitive decline (6, 9).

Without ignoring the importance of nutritional and lifestyle modification interventions, physical exercise is the primary therapeutic strategy for the prevention of disease and associated decline in functional capacity (10). Evidence suggests that enriching physical exercise interventions with a cognitive challenge could maximize the neuroplastic properties of physical exercise. The additive effects of cognitively demanding physical exercise could be explained by the temporal nature of peripheral brain-derived neurotrophic factor (BDNF), which returns to basal levels 10–60 min after physical exercise, requiring a temporal succession of cognitive demands to optimally benefit from these neurotrophic effects (11). Furthermore, the brain plasticity favored by increasing cell proliferation and synaptic plasticity is "guided" by cognitive training by increasing the number of new-born neurons that survive and their integration in new neural networks, as well as the increased number of synapses in preexisting neural networks (12). It has been suggested that these effects could be observed regardless of age, and therefore cognitive decline could be preventable (13).

Aims

The purpose of this paper is to describe the protocol of the MOVI-ageing randomized controlled trial, a home-based eHealth intervention of cognitive-demanding exercise for older adults, in improving global cognitive function and basic cognitive functions, cardiorespiratory fitness, and muscle fitness.

Methods

Design

For the design of this protocol, the CONSORT guidelines for randomized controlled trials studies (14) and the Consolidated Criteria for Reporting Qualitative Studies (COREQ) (15) were used. The MOVI-ageing randomized controlled trial will include a mixed design, following quantitative and qualitative approaches.

The quantitative study will be developed in two phases: (i) an efficacy and feasibility study and (ii) an implementation study. The former will be aimed at testing the efficacy of the MOVI-ageing intervention in improving key outcome variables, refining the intervention, and examining potential biases of the intervention. During this phase, a qualitative approach will be used as feedback to define the development of the platform, as evidence indicates that when users are involved in the design and evaluation of the feasibility study, the efficacy of the implementation increases. The latest will be developed following the same methodological procedures to test the MOVI-ageing intervention in a larger sample size.

Recruitment and allocation

The Clinical Research Ethics Committee of the 'Virgen de la Luz' Hospital in Cuenca has approved the study protocol (registration number: 2022/PI3222). The development of this project will be supported by the Health Care Services of Cuenca. In addition, this protocol has been previously registered in Clinicaltrials.gov (Number: NCT05928078).

Potential participants will be accessed through key informants in the social centers of Cuenca and Talavera de la Reina. The research team will contact the potential participants by phone to offer them participation in the study. In addition, flyers and posters will be located in places where older people could potentially develop leisure activities (including but not limited to libraries and older adults' centers) with the contact information of the research team.

During the information process of the participants, the research team will inform them that they can drop out of the study as they request. After agreement to participate and informed consent, participants will be randomly distributed (1:1) to the intervention (IG) or control group (CG) using EPIDAT 4.2 software (Figure 1).

Although the application of a physical intervention program cannot be blinded to participants, the investigators involved in measurements will be blinded to the group to which the participants belong. With the same aim, each participant will receive an identification number to blind his/her allocation during the analysis of data. The identification number and the personal data of the participants will be stored in different data bases and will be crossed only in case to detect anormal values during the measurement processes.

Participants: inclusion and exclusion criteria

Participants will be invited to participate when meeting the following inclusion and exclusion criteria.

Inclusion criteria. Individuals: (1) aged 60–80 years of both genders; (2) retired regardless of the reason for retirement; (3) not meeting frailty criteria according to Fried criteria; (4) are without disabilities for activities of daily living; (5) live independently; (6) without cognitive impairment as determined by the Mini-Mental test greater than 24 (considering the degree of schooling of the participants); and (7) able to walk at least 20 meters with or without walking aids.

Exclusion criteria. Individuals will be excluded when they have any of the following: (1) mobility problems; (2) serious health problems (e.g., recent myocardial infarction, uncontrolled diabetes, or uncontrolled hypertension); (3) orthopedic or neurological disease that prevents training; (4) Alzheimer's disease or dementia; (5) progressive or terminal illness; (6) acute or chronic illness; (7) history of heart attack; (8) history of vertigo or recent head injury; (9) health problems that may affect the ability to perform physical exercise (e.g., acute and painful joint inflammation, impaired joint function, acute and painful joint inflammation, or deterioration in the ability to perform physical exercise); (10) intake of medications that act at the neuron level (e.g., psychotropic medications); (11) signs of incipient depression; or (12) pathology that impedes the use of the computer application through which the physical exercise program will be developed.

MOVI-ageing intervention: description

The MOVI-ageing intervention will be developed as a randomized controlled trial with two arms in which participants will be randomly assigned to the IG, in which a home-based e-Health intervention of cognitively demanding exercise will be performed, or to the CG in which participants will continue their regular daily activity.

The e-Health intervention will be delivered using a platform including videos that will guide the participants in the realization of the movement during the cognitively demanding physical exercises. The participants will follow the videos remotely and off-line, and the users will have to imitate the movements of the trainer. Through the platform, it will be possible to evaluate the degree of compliance with the exercise program and the correct performance, as the system will accurately track and measure the participant's limb movement through the camera and provide the research team with an objective measure of the patient's movements and progress. Research team will be able to check this information during the development of the session or at any time of the clinical trial duration.

The recorded videos, designed by a team of experts including nurses, psychologists, physical activity graduates, and geriatricians, will include cognitively demanding exercises involving both basic cognitive functions (i.e., inhibition, working memory, and cognitive flexibility) and higher cognitive functions (i.e., spatial orientation, numerical calculation, and semantics). Each video will include a standardized physical exercise program structured as follows: 5 min warm-up (including animation and/or joint mobility activities), three blocks of 4 min at 65–75% of the maximum heart rate (including aerobic and muscle strength activities) without cognitive demand, three blocks of 4 min at moderate intensity including cognitively demanding activities, and 10 min of cool-down (including balance activities, breathing-relaxation exercises, and/or muscle stretching) (Figure 2).

To ensure the standardization of the program, at the beginning of the intervention, participants in the IG will attend a 2-h training session for the use of the platform and will be instructed in the control of their heart rate during the execution of the physical exercise program to be able to control the intensity of the physical exercise they perform. Users will be provided with indications to carry out the activities and will be required to perform at least 3 sessions per week of cognitively demanding physical exercise through the platform for 12 weeks.

Criteria for nonadherence and prolongation of training

Compliance with the exercise program will be regularly monitored through the intervention. To be considered in the analyses, participants must attend at least 70% of the sessions. If, due to unexpected circumstances, a participant does not comply with the exercise program within the 12 weeks, the training program may be extended for up to 4 weeks. Finally, in case of unexpected adverse effects of the intervention, the participant will be clinically followed-up, and the research team will record the reasons for drop out.

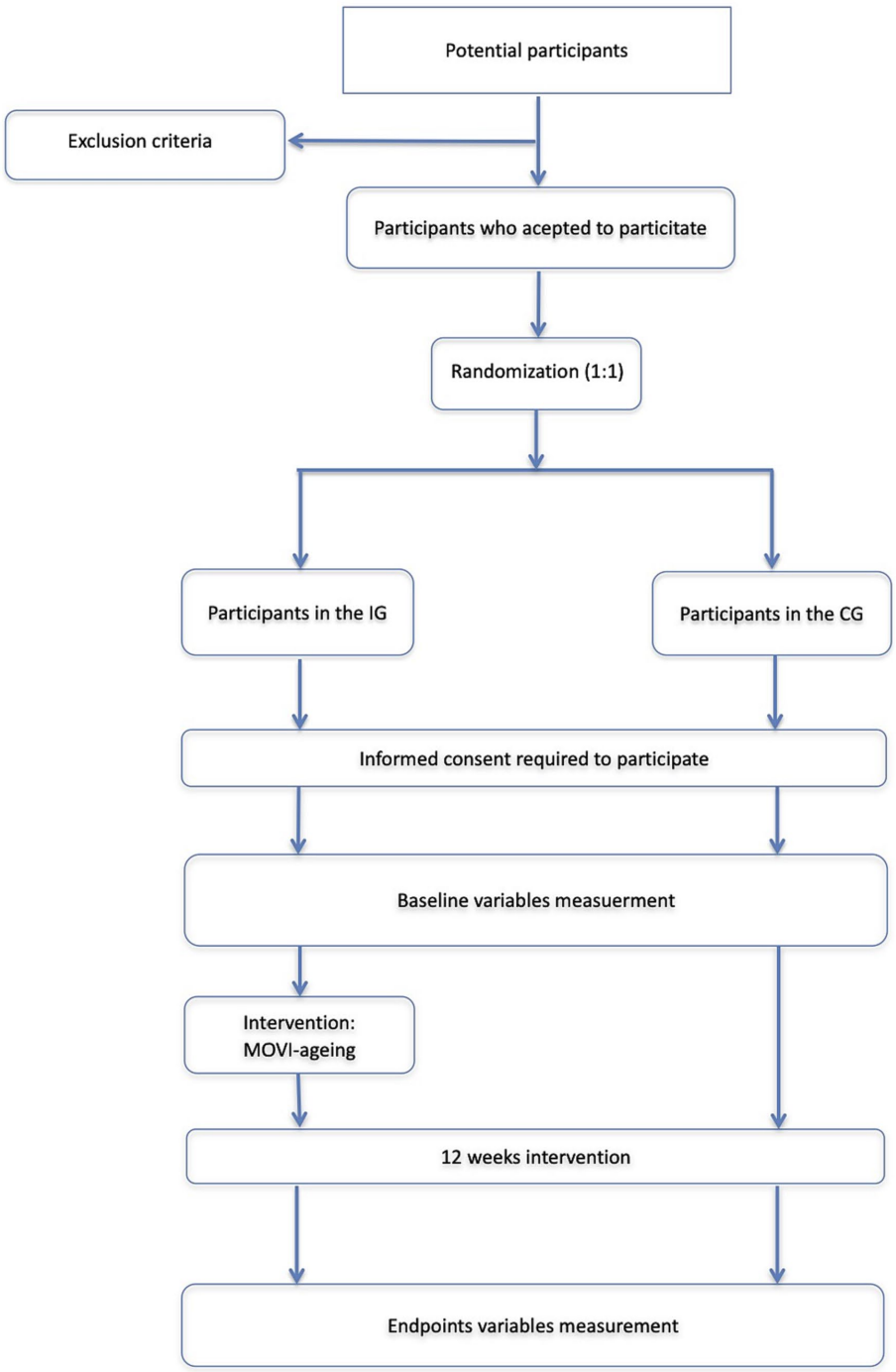

FIGURE 1
Flow chart of trial participants. CG, control group; IG, intervention group.

MOVI-ageing: monitoring and adherence

To improve adherence to the intervention, a telephone number and an email address will be available for participants for any doubt or information they need. Weekly information on the amount of physical activity performed will be emailed to the participants. The research team will contact participants monthly to check their satisfaction with the intervention.

Variables

Measurement of the variables will be performed on all participants at the beginning and at the end of each phase of the study. Each participant will be scheduled at the facilities of the research team to carry out the measurements of all variables on a single day, and investigators will be previously trained to standardize

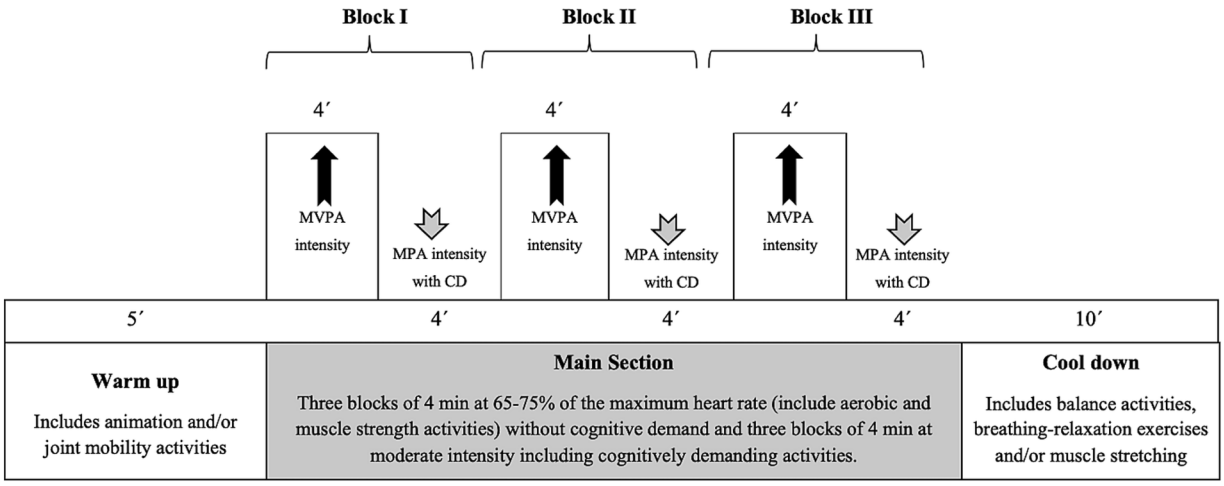

FIGURE 2
Basic design of a MOVI-ageing session. MVPA, Moderate-vigorous physical activity; MPA, moderate physical activity; CD, cognitive demands.

the measurements. The variables will be measured following standardized and validated processes with the following tools (Table 1):

(1) Basic executive functions: using the NIHtool (16) and including (a) Attention using the Eriksen flanker Task test where a 40-trial block will be presented consisting of a pseudorandom sequence of congruent and incongruent trials. Scoring will be calculated based on accuracy and reaction time; (b) Working memory using an adaptation of the Mungas List Sorting task where a series of illustrated pictures will be presented visually and orally. Participants will be asked to verbally repeat the names of the pictures in order of size, from smallest to largest. Two list versions will be presented, the first presenting items in one category (i.e., animals), and the second presenting items in 2 categories (i.e., animals and food) in which participants will be asked to organize items by category and size; and (c) cognitive flexibility using the DCCS (Dimension Change Card Sort) test. This tool will present a 30-trial block of mixed by "color" or "shape" stimulus, where participants will be asked to adapt their response according to the relevant dimension.

(2) Global cognitive function with the Mini-Mental State Examination (MMSE) (17), which consists of 30 items grouped into 11 categories (including visual space, memory, naming, attention, calculation, abstract, orientation, and language function), with higher scores representing better cognitive functioning. The MMSE has been widely used in older people and has excellent reliability and validity (18). In this study, cognitive impairment will be defined as an MMSE score of less than 24 for respondents with 8 years of education or more and less than 20 for those with less than 8 years of education (19).

(3) Health-related quality of life (HRQoL) with the SF-12 test (20), which aimed to evaluate the intensity and/or frequency of people's state of health. The scale is composed of 12 items that could be answered by a Likert-type scale. This questionnaire provides information on eight subscales: physical functioning, physical role, bodily pain, general health, vitality, social functioning, emotional role, and mental health. These eight subscales comprise the physical and mental domains of patients' HRQoL, where the higher the score is, the better the HRQoL. The SF-12 is a valid and reliable instrument.

TABLE 1 Study variables.

Type of variable	Specific variables
Primary endpoints	Executive function: inhibition, working memory and cognitive flexibility
	Global cognitive function
Secondary endpoints	Health-related quality of life
	Depression, anxiety, and stress
	Cardiorespiratory fitness
	Muscle strength
Other endpoints	Physical activity: accelerometry
	Physical function
	Concern of falling
	Anthropometry: weight, height, BMI
	Body composition: waist circumference, body fat, body composition
	Blood pressure:
	Blood tests: Fasting plasma glucose, apolipoproteins A1 and B, insulin ultrasensitive protein C, HbA1c, and BDNF
	Markers of atherosclerosis: PWv, rAIx, cAIx, endothelial function, and 24-h blood pressure
	Food consumption
	Sleep habits and quality of sleep
	Comorbidities
Possible confounding factors	Age
	Sex
	Level of education

BMI, body mass index; cAIx, central augmentation rate; HbA1c, hemoglobin glucose; PWv, pulse wave velocity; rAIx, radial augmentation rate.

(4) Depression, anxiety, and stress will be assessed with Yesavage's 15-item Geriatric Depression Scale (GDS) questionnaire (21, 22), which includes questions related to affect, in-activity, irritability, isolation, distressing thoughts, or negative judgments. The questions have dichotomous answers (yes/no) regarding the last week.

(5) Cardiorespiratory fitness measured with the 6-min walking test (6MWT), where participants will be instructed to "walk as far as possible" for 6 min back and forth along a corridor 100 feet in length (23). Participants will be encouraged to walk but permitted to slow down, stop, and rest when needed. This test reflects the overall functional ability and the impact of multiple factors on exercise capacity (24).

(6) Muscular strength will be measured by upper extremity dynamometry with the digital TKK 5401 Grip-D (Takey®, Tokyo, Japan). This test measures the upper body strength in kilograms. The test will be performed twice with the right hand and twice with the left hand; the mean average of the 4 measurements will be calculated.

(7) Physical activity will be measured with the Axivity 6-axes accelerometers (Axivity LTd.) for seven consecutive days (including nights), with a fixed frequency of 30.0 Hz to collect raw acceleration data measured in "g" for each movement axis (x, y, and z). Data will be expressed in units of milligrams ($1{,}000\,mg = 1\,g = 9.81\,m/s^2$). We will consider as valid registers of ≥5 days, including 1 weekend day.

(8) Physical function will be measured with the Short Portable Physical Battery scale (SPPB), (25) which measures balance, walking speed, and standing up and sitting on a chair 5 times. During the balance test, the participants will be required to maintain 3 positions for 10 s each: feet together, semitandem, and tandem. In the walking speed test, the participant will be encouraged to walk a 4 m distance at his/her usual pace. This test will be performed 2 times, and the shortest time will be recorded. Finally, the total time the participant spent standing up and sitting 5 times on a chair will be recorded. Each test could be scored from 0 (worst performance) to 4 (best performance). In addition, the score for the total battery will be the sum of the 3 tests and ranges from 0 to 12.

(9) The concern of falling with the Falls Efficacy Scale International (FES-I) (26), which includes the possibility of falling when performing 16 different everyday life activities. Each item could be classified as follows: 1 = not at all concerned, 2 = somewhat concerned, 3 = fairly concerned, and 4 = very concerned. The total score could range from 16 to 64, with lower scores indicating a low fear of falling.

(10) Anthropometric variables, including (i) Weight measured with a Seca® 861 scale, with the participant barefoot and lightly dressed; (ii) Height: measured with a Seca® 222 wall-mounted stadiometer, with the participant barefoot and in an upright position while the sagittal midline of the back touches the vertical bar; and (iii) Body mass index (BMI) calculated using the mean of the two measurements of weight and height as follows: weight (kg)/height^2 (m^2).

(11) Body composition, including (i) waist circumference reported as the mean of three measurements using a flexible tape measure at the midpoint between the last rib and the iliac crest at the end of a normal exhalation. (ii) Body fat percentage reported as the mean of two measurements using an eight-electrode Tanita® Segmental-418 bioimpedance system (Tanita Corp. Tokyo, Japan). And (iii) Body composition by densitometry (DXA), which allows us to determine fat mass, lean mass, bone density, and bone mineral content.

(12) Blood pressure measured using an OMRON® HEM-907 and reported as the mean of two measurements 5 min apart and after a 5-min rest period.

(13) Biochemical determinations, including (1) Fasting plasma glucose, apolipoproteins A1 and B, insulin ultrasensitive protein C and endothelial glycocalyx (syndecan-1, syndecan-4 and heparan sulfate proteins) with the Abbott® Cobas 8000 Roche Diagnostics® system; and (2) HbA1c, determined by HPLC (high-performance liquid chromatography) using the ADAMS A1c HA-8180V analyser (Menarini Diagnostics®), a method certified by the NGSP (National Glycohemoglobin Standardization Program) and the IFCC (International Federation of Clinical Chemistry and Laboratory Medicine). In addition, BDNF will be measured by enzyme-linked immunosorbent assay (ELISA) (R & D Systems, Minneapolis, MN, USA).

(14) Subclinical markers of atherosclerosis and vascular function, including (1) pulse wave velocity (PWv), radial augmentation rate (rAIx), and central augmentation rate (cAIx), which will be measured with the SphygmoCor system (AtCor Medical Pty Ltd. Head Office, West Ryde, Australia); (2) endothelial function: with the ENDO-PAT; and (3) 24-h blood pressure with the MAPA Mobil-O-graph.

(15) Adherence to the Mediterranean diet will be measured with the Mediterranean Diet Adherence Screener (MEDAS) questionnaire (27), which includes 12 questions on food consumption frequency and 2 questions on food intake habits considered characteristic of the Spanish Mediterranean diet. Each question will be scored 0 or 1, where the final score could range from 0 to 14.

(16) Sleep habits and quality of sleep will be measured with the Pittsburgh Sleep Quality Index (PSQI) (28), which consists of 24 questions, including 19 self-reported and 5 that require secondary feedback from a room or bed partner. Only the self-reported items will be used for the quantitative evaluation of sleep quality, with scores ranging from 0 to 21.

(17) Comorbidities measured with the Charlson comorbidity index (29), which consists of the register of 17 comorbidities, with two subcategories for diabetes and liver disease. The total score will be summed from the weighted total mortality risk and disease severity.

(18) Level of education: measured as the highest level of education achieved by each participant, classified as: cannot read or write, no education, incomplete primary education, primary education, high school graduation, high school graduation, intermediate university studies, or higher university studies.

It should be considered that measurement of accelerometry, body composition with DXA, biochemical determinations, and subclinical markers of atherosclerosis will only be performed in the efficacy and feasibility study.

Statistical analysis

Sample size

Previous studies (30) have shown that a combined program of exercise and cognitive training for 3 months can improve working memory in cognitively healthy older adults, with an approximate effect size of 0.9. Considering the characteristics of our study and using GPower software, we calculated that a sample size of 21 participants per group would be needed to achieve a power of 0.8, with an alpha of 0.05 and a beta of 0.2. Assuming a dropout rate of 15%, a final sample size of 24 participants per group would be required for the efficacy and feasibility study. The sample size for the implementation study will be calculated based on the results of the previous phase.

Analyses of outcomes

After measurements, participants' data will be entered into a database by two independent researchers. Blinding on handling data will be assured by separating measurement values from general participant information.

The statistical analysis plan can be summarized as follows: (i) after checking that randomization has been effective, we will winsorize the variables to limit the influence of extreme values; this will be done by replacing values below the 1st percentile with the 1st percentile value and those above the 99th percentile with the 99th percentile value. (ii) Mixed regression models will be used in which each outcome variable will be the dependent variable, interventions will be treated as fixed effects (1 = IG and 0 = CG), and the models will be adjusted for baseline reference values and age. The results will be expressed as absolute differences in changes in the variables between baseline and final measurement. When the dependent variable is dichotomous, odds ratios (ORs) will be calculated. Finally, (iii) analyses will be conducted from an intention-to-treat perspective, whereby participants will remain in the group to which they were originally assigned, regardless of the degree of compliance with the intervention.

The results will be considered statistically significant when $p < 0.05$. The analyses will be performed using STATA16.

Qualitative approach

A qualitative study will be carried out following Giorgi's phenomenological approach with the aim of describing the meanings of phenomena from participants' experiences (31, 32). The information obtained from the qualitative study on barriers to and facilitators of the implementation of the cognitively demanding physical exercise intervention using eHealth for older people will be used to adapt the MOVI-ageing application.

Focus groups will be used because of their capacity to generate in-depth information on the perceptions and opinions of the phenomenon through the interaction of the participants and to explore a wide variety of opinions on the subject (33). Giorgi's descriptive phenomenology approach will be used to explore the barriers and facilitators of older people's use of a computer application for physical exercise, information that will guide the development and implementation of the MOVI-ageing intervention (31). As a data collection technique, focus groups will be conducted in a purposive sample of homogeneous groups of older people of both genders (men and women), socioeconomic level (low, medium, high), educational level (university or intermediate level studies, school graduate, no studies) and physical condition (assessed with the SF-12 scale). The criteria of intragroup homogeneity and intergroup heterogeneity will be followed to ensure that participants can express themselves freely.

The focus groups will be conducted by experts in qualitative methodology who will share a common protocol that will include the methodology of data collection and the script of topics. Each focus group will have a moderator, who will have the script of themes, conduct the focus group, and launch the questions, and another researcher who will act as an observer. The focus groups will be conducted in a neutral, comfortable, quiet, and private place, will last between 60 and 120 min, will be audio-recorded after obtaining the participants' permission, and will include between 5 and 8 participants per group. At least two focus groups will be conducted, but the final number will be conditioned by the data saturation criterion to be reached when no novel analytic information is obtained (34).

Data collection and analysis will follow an interactive circular process so that the data collected in each focus group will serve to refine the topic script of the following groups. In addition, all data will be compared to each other through the constant comparison method. As data verification strategies, the focus groups will be audio-recorded and transcribed verbatim and subsequently anonymized for analysis. In addition, the interview transcripts will be returned to the participants for their agreement with the interviews. During the analysis phase, data will be grouped into themes and subthemes following the following steps of Giorgi's phenomenological approach: (1) collect and describe phenomenological data, (2) read the full description in the transcribed texts, (3) break descriptions into meaning units that are as descriptive as possible, avoiding precocious interpretation of the results, (4) group the units by common meanings, forming clusters of meanings, and (5) interpret the clusters of meanings and identify the themes that will show the meaning of the phenomenon (31). Two researchers with expertise in qualitative methodology will independently perform the data analysis, subsequently agreeing on the results; in case of disagreement, a third researcher will mediate. The triangulation of data by three researchers will allow the emergence of different perspectives and deepen the analysis, increasing the validity of the findings. Atlas-ti 9.0 software will be used as an aid during this phase. The credibility, transferability, reliability or dependability, and confirmability criteria of Guba and Lincoln will be followed to ensure the reliability of the study (35, 36).

Discussion

Physical exercise stimulates neuroplasticity processes, producing effects on brain structure, function, and connectivity. Exercise causes a change in the metabolic activity of the brain, increasing cerebral blood flow resulting in increased oxygen and glucose metabolism, as well as promoting cardiovascular function and thus reducing peripheral cardiovascular risk factors (e.g., hypertension) for cognitive impairment (37–40). Improved cognitive performance has also been

linked to several growth factors whose expression is related to physical exercise, such as insulin-like growth factor 1 (IGF-1), which promotes neuronal growth and improves cognitive performance, and vascular endothelial growth factor (VEGF), which stimulates angiogenesis and vasculogenesis and promotes tolerance to cerebral ischemia (41, 42).

In addition, physical exercise activates BDNF (43), which plays a crucial role in neuroprotection and synaptic plasticity by promoting neurogenesis, cell proliferation, and synaptogenesis in the hippocampus, as well as angiogenesis in other brain areas (44, 45). Finally, exercise contributes to improving memory by elevating dopaminergic activity in the basal ganglia and elevating blood concentrations of other biomarkers (norepinephrine, lactate, etc.) and reduces inflammatory cytokines and oxidative stress, suggesting anti-inflammatory and antioxidant effects in the brain (46, 47).

Considering the benefits of physical exercise for older individuals, it does not seem a good practice to avoid prescribing physical exercise for these individuals. Despite this, physical exercise recommendations have not been fully integrated into primary or geriatric medical practice and are almost absent in the basic training of most health professionals (48). One of the main reasons is the lack of specific tools and recommendations, as even the WHO does not distinguish in its physical activity recommendations between different specific conditions among older people.

Although previous experiences are an important source of evidence, we still lack interventions that are applicable, suitable for all people regardless of gender, and supported by a user-friendly platform. Interventions are needed that include behavior modification models, including active participant learning, intrinsic motivation, self-awareness, and learning over time (49). In addition, these interventions should be culturally adapted and based on individual preferences, accessible to large population groups at low cost, and easily reproducible, including ongoing and personalized support advice. In view of the above, it seems necessary to evaluate the effectiveness of a cognitively demanding cognitive physical exercise home-based eHealth intervention from a population perspective.

This study has some limitations that should be recognized. Although this is a randomized controlled trial, it will not be possible to blind participants to the allocation group, and some bias could be derived from this fact. Second, the measurements and intervention program sessions will be standardized by training the staff, but some variability could not be neglected. Finally, a program based on physical activity will be designed without considering diet interventions, although adherence to Mediterranean diet will be collected, other diet behavior information will not be available.

Implications

The results of this project aim to impact in the QoL and the well-being of a specific group of population with the objective to cover their needs. The implementations of the findings and their inclusion in guidelines, may directly impact in older people's life and relatives, through the prevention of morbidity and the reduction of years lost to disability. These benefits may be reflected in the reduction of economic expenditure by reducing the demand for social and health care services.

Strengths and limitations of this study

Cognitively demanding physical exercise has been proposed to foster cognitive function regardless of age.

This study aims to describe the protocol of a home-based eHealth cognitive-demanding exercise intervention for older adults in cognitive and physical function.

The inclusion of patients in the design of interventions allows them to culturally adapt to individual preferences and improve the participants' adherence.

The development of the eHealth intervention in two phases and the inclusion of the qualitative approach will ensure the adaptation of the intervention to users' preferences.

Ethics statement

The studies involving humans were approved by the Clinical Research Ethics Committee of the 'Virgen de la Luz' Hospital in Cuenca approved the study protocol (registration number: 2022/PI3222). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

CA-B: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft. ML-L-T: Investigation, Methodology, Writing – review & editing. AR-H: Conceptualization, Investigation, Methodology, Writing – original draft. IS-D: Investigation, Writing – original draft. LV-S: Conceptualization, Investigation, Methodology, Writing – review & editing. MM-E: Conceptualization, Investigation, Methodology, Writing – review & editing. MV-A: Investigation, Methodology, Validation, Writing – review & editing. BR-M: Conceptualization, Funding acquisition, Investigation, Methodology, Writing – review & editing.

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Conflict of interest

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

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Glossary

BDNF	brain-derived neurotrophic factor
BMI	Body mass index
cAIx	central augmentation rate
CG	Control Group
COREQ	Consolidated Criteria for Reporting Qualitative Studies
DCCS	Dimension Change Card Sort
ELISA	Enzyme-linked immunosorbent assay
FES-I	Efficacy Scale International
GDS	Geriatric Depression Scale
HRQoL	Health-related Quality of Life
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine
IG	Intervention Group
IGF-1	insulin-like growth factor 1
MEDAS	Mediterranean diet adherence screener
MMSE	Mini-Mental State Examination
NGSP	National Glycohemoglobin Standardization Program
OR	odds ratio
PSQI	Pittsburgh Sleep Quality Index
QoL	Quality of Life
rAIx	radial augmentation rate
SF-12	12-Item Short Form
SPPB	Short Portable Physical Battery scale
WHO	World Health Organization
6MWT	6-minute walking test

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Impact of cardiovascular disease on health-related quality of life among older adults in eastern China: evidence from a national cross-sectional survey

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Objective: This study explores the health-related quality of life (HRQoL) scores of Chinese older adults with Cardiovascular Disease(CVD) using the EQ-5D-3L, the aim of this study is to investigate the association between health and HRQoL in older adults with CVD.

Methods: The data for this study were obtained from a cross-sectional study involving older adults residing in Chinese communities The EQ-5D-3L is used to measure the HRQoL scores in the older adults with CVD. One-way analyses were conducted using the Wilcoxon rank sum test and the Kruskal–Wallis H test to assess differences between groups. A binary logistic regression model was employed to analyze the influence each variable has on the presence of "any problem" on each dimension of EQ-5D-3L in older adults with CVD. An ordinal least squares (OLS) model is used to assess the relationship between older adults with CVD and HRQoL.

Results: The mean EQ-5D-3L score for older adults with CVD is 0.774. 40.0% of older adults with CVD reported problems with pain/discomfort, followed by Mobility (35.9%), Self-care (31.5%), and Anxiety/depression (17.0%). Binary logistic regression models show that financial resources were the main factor influencing the five dimensions of EQ-5D-3L. The OLS model further indicates that younger age, financial resources, and a lower number of chronic conditions among older adults with CVD are associated with higher HRQoL scores.

Conclusion: Chinese older adults with CVD have low HRQoL scores. Variousfactors influence both overall HRQoL scores and scores on each EQ-5D-3L dimension. This study is helpful in enhancing society's attention to the HRQoL of older adults with CVD and taking targeted measures to improve them.

KEYWORDS

health-related quality of life, cardiovascular disease, EQ-5D-3L scale, older adults, Eastern China

1 Introduction

Cardiovascular diseases (CVD), is a group of disorders that affect the heart and/or blood vessels and is now the leading cause of death, contributing to one-third of global deaths per year (1, 2). Growing evidence confirms that CVD incidences increase cardiovascular and all-cause mortality, especially among the older adults (3). In the 2019 American Heart Association data, the prevalence of cardiovascular disease averaged 75–78% in older adults with CVD aged 60–80 years and more than 85% in older adults with CVD aged 80 years and older (4). Some studies have indicated that gender significantly affects CVD incidence, in generally, before menopause, women are relatively protected from cardiovascular disease, and then, after menopause, the risk for cardiac disease greatly increases in women, leading to gender differences in outcomes between men and women attributable in large part to sex hormones and their associated receptors (5, 6). The world's older adults continues to grow at an unprecedented rate. According to China's 7th Census, 18.7% of people (617 million) in China are 60 years and older (7), and it is estimated that 4 million deaths are due to cardiovascular diseases each year in China (8). CVD and its treatments pose significant burden on patients' health-related quality of life (HRQoL) and can affect their ability to function.

HRQoL is often used to assess the health status of patients, reflecting the patient's physical, psychological, social, and emotional well-being (1). Moreover, HRQoL is considered an important patient-reported outcome measure for interventions and treatments in patients with CVD (9). With the public's interest in HRQoL, more and more leaders are applying HRQoL to clinical care, preventive care, and health economic evaluation (10). The levels and determinants of HRQoL in the general population have been well documented in developed and developing countries (11–14). Several generic and disease-specific tools have been developed for measuring HRQoL of patients with CVD (15, 16). EQ-5D is a handy, easy-to-use tool for measuring health outcomes. The validity and reliability of EQ-5D have been tested in populations in mainland China (17, 18). And the EQ-5D-3L instrument has been validated in Chinese people and is being increasingly used for assessing HRQoL in people living with chronic conditions (19–22).

HRQoL is considered an important patient-reported outcome measure for interventions and treatments in patients with CVD (14, 21, 23). Although some previous studies also have reported the association between CVD and HRQoL; however, less is known about the association between cardiovascular health and HRQOL (24, 25). Accordingly, the aim of this study was to investigate the association between health and HRQoL in older adults with CVD. These findings may help provide a rationale for developing targeted interventions for older adults to improve patient health outcomes.

2 Method

2.1 Data collection

In this study, the eastern region is chosen as the target of the study. This cross-sectional investigation was conducted from September 2021 to December 2021 by the public health staff in the household survey. A multi-stage stratified sampling method was selected for this study. In the first stage, three provinces were randomly selected from 12 provinces in the eastern region, namely Shandong Province, Jiangsu Province and Guangdong Province. Secondly, one municipality was randomly selected from within each province. Qingdao in Shandong Province, Suzhou in Jiangsu Province and Guangzhou in Guangdong Province. In the second stage, a county/district was randomly selected within the jurisdiction of each city. Qingdao was chosen as Jimo District, Suzhou was chosen as Kunshan County and Guangzhou was chosen as Yuexiu District. Next, two streets were randomly selected from each city/district. Finally, two communities were randomly selected from each street. In the third stage, researches were randomly selected from each community.

Inclusion criteria: (1) age $\geq$ 60 years, (2) receiving community-based home services for 6 months or more, (3) being conscious and able to communicate normally, (4) voluntarily participating in this survey. Exclusion criterion: (1) severe cognitive impairment, (2) severe memory impairment. Therefore, 1,380 questionnaires were collected, missing values of key variables were excluded from the data, and 1,291 valid questionnaires were recovered. Older adults with CVD were screened out, and 756 older adults were finally included. The recruitment process of participants is shown in Figure 1.

2.2 HRQoL score using EQ-5D-3L

The EQ-5D-3L was used to report the health status and evaluate the HRQoL score of older adults with CVD. The EQ-5D is the most commonly used quality of life scale in health research and as a generic preference based measure of HRQoL, it can be validly applied across participant groups and intervention types. The EQ-5D has been extensively studied and has been shown to have excellent reliability and validity, while the new 5 level version (as used in the current study) has been shown to reduce ceiling effects seen in people with minor health related quality of life impairments.

EQ-5D-3L has five dimensions: Mobility (MO), Self-care (SC), Usual Activities (UA), Pain/Discomfort (PD), and Anxiety/Depression (AD) Each dimension has three levels: no problem, some problems, and extreme problems.

Liu et al. (26) used the TTO method to translate the EQ-5D-3L measurements into scores. The EQ-5D-3L theoretically produces 243 health states (27). The EQ-5D-3L utility scores can be calculated according to Table 1, where C indicates a constant; MO2, SC2, UA2, PD2, and AD2 represent level 2 problems in mobility, self-care, usual activities, pain/discomfort, and anxiety/depression.; MO3, SC3, UA3, PD3, and AD3 represent the presence of level 3 problems in five dimensions of the scale, and N3 indicates that at least one dimension is at level 3. For example, the utility score of $32{,}213 = 1 - (0.039 + 0.246 + 0.105 + 0.074 + 0 + 0.205 + 0.022)$. The range of values is [−0.149 to 1]. The upper limit of effectiveness value is 1, which means that the state of full health is 11,111, and the lower limit is −0.149, which means the worst state of health is 33,333.

2.3 Statistical analysis

Descriptive statistics were calculated for all measures. Means and standard deviations (SD) were presented for continuous variables, while frequency and percentages were used for categorical variables. A chi-squared test was used to compare the differences in the reported

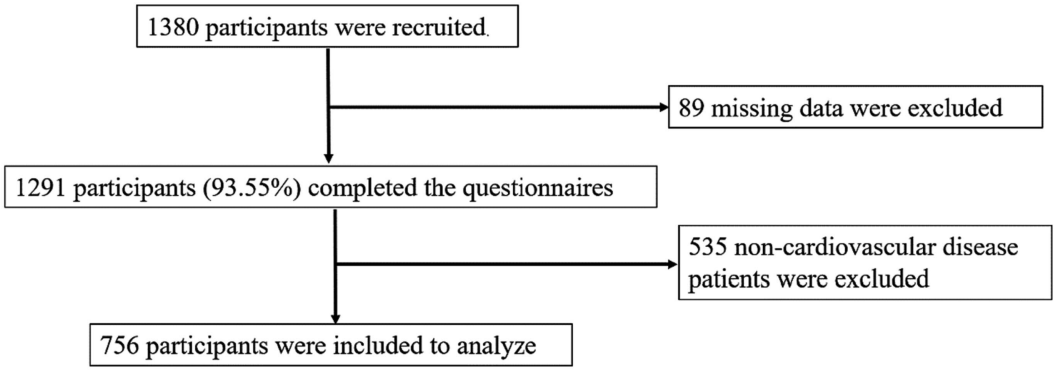

FIGURE 1
Flowchart on participant recruitment.

TABLE 1 Chinese utility values of EQ-5D-3L health status.

C	MO2	MO3	SC2	SC3	UA2	UA3	PD2	PD3	AD2	AD3	N3
0.039	0.099	0.246	0.105	0.208	0.074	0.193	0.092	0.236	0.086	0.205	0.022

problems on each dimension of EQ-5D-3L across different groups. Since the EQ-5D-3L index scores were not normally distributed (Shapiro–Wilk test, $p < 0.05$). One-way analyses were performed using the Wilcoxon rank sum test and the Kruskal–Wallis H test to assess the differences in EQ-5D-3L scores between groups. A binary logistic regression model was used to predict the probability of participants reporting full health (0 and 1, where 0 indicates no problem and 1 indicates any problem reported) on each of the three dimensions of EQ-5D-3L. The ordinal least squares (OLS) model was used to explore the relationship between CVD and EQ-5D-3L score. Because ceiling effects are a common problem for EQ-5D-3L scores, we also performed Tobit regression analyses, which were consistent with those of OLS (see Supplementary Table S1).

3 Results

3.1 Participants' characteristics

Females constituted 55.8% of the cohort, 33.0% were aged 60–70 years and 25.5% were 70–80 years of age. More women (23.1%) than men (15.7%) were above 80 years of age and also more women (14.2%) than men (12.5%) were between 70 and 79 years of age. The largest percentages of other variables were elementary school education (31.9%), income <$1,000 (34.5%), have three or more chronic diseases (48.1%), and sleep for 6–8 h (21.3%). See Table 2.

3.2 The EQ-5D-3L scores of older adults with CVD by gender

The HRQoL among older adults with CVD using the EQ-5D-3L was 0.774. 42.4% of older adults with CVD have a health index = 1 and are in perfect health. Females have a slightly higher health score (0.777) than males (0.770). Male and female older adults with CVD, who are younger, have a spouse, are highly educated, are financially independent (pension and other sources of income), live with their families, have a low number of chronic diseases, do not drink alcohol, and have a moderate amount of sleep, had higher HRQoL scores. See Table 2.

The distribution of HRQoL scores by gender and for all older adults with CVD is shown in Figure 2.

3.3 Proportion of the five dimensions of EQ-5D-3L with any problems

Table 3 shows the percentage of the any problems response for each dimension of the EQ-5D-3L. The study results show that the five dimensions of PD, UA, MO, SC, and AD are problematic at 40.0, 36.2, 35.9, 31.5, and 17.0%, respectively. The proportion of older adults with CVD with the any problem response in each dimension is lower for those who are younger, financially independent (pension and other sources of income), and have fewer types of chronic diseases than the other groups. Older adults with CVD with a spouse, high literacy, and non-drinking behavior have lower proportions of the any problem response in the PD, MO, and UA dimensions than other groups. The proportion of older adults with CVD living with family members who had "any problem" in the PD, MO, UA, and SC dimensions was lower than in the other groups. Older adults with CVD with a monthly income of ¥3,001–5,000 have a higher proportion of the any problems response in the PD, MO, UA, and AD dimensions than any other group.

3.4 A binary logistic and OLS regression model of responses to the EQ-5D-3L

A binary logistic regression model was used to analyze the influence of each variable on the presence of the any problem response on each dimension of EQ-5D-3L in older adults with CVD. The study results show that financial resources affect the five dimensions of MO,

TABLE 2 The EQ-5D-3L score of the older adults with CVD (stratified by gender).

Variable	Total			Male		Female	
	n (%)	Mean (SD)	*p*	Mean (SD)	*p*	Mean (SD)	*p*
Age(years)			<0.001		<0.001		<0.001
60–70	263 (34.4)	0.875 (0.207)		0.842 (0.243)		0.904 (0.164)	
70–80	205 (26.8)	0.797 (0.247)		0.771 (0.274)		0.820 (0.219)	
>80	297 (38.8)	0.669 (0.295)		0.696 (0.298)		0.650 (0.293)	
Spouse			<0.001		<0.001		<0.001
Yes	490 (64.1)	0.825 (0.241)		0.812 (0.261)		0.834 (0.223)	
No	275 (35.9)	0.684 (0.294)		0.692 (0.295)		0.678 (0.294)	
Education			<0.001		0.003		<0.001
Illiteracy	223 (29.2)	0.694 (0.315)		0.694 (0.335)		0.64 (0.309)	
Primary school	244 (31.9)	0.775 (0.267)		0.730 (0.290)		0.816 (0.237)	
Junior high school	152 (19.9)	0.840 (0.212)		0.830 (0.235)		0.852 (0.182)	
High school and above	146 (19.1)	0.827 (0.217)		0.827 (0.233)		0.826 (0.200)	
Financial resources			<0.001		0.003		<0.001
Pension	418 (54.6)	0.796 (0.259)		0.780 (0.280)		0.810 (0.238)	
Support from family and friends	189 (24.7)	0.680 (0.308)		0.679 (0.311)		0.681 (0.308)	
Others	158 (20.7)	0.828 (0.218)		0.831 (0.217)		0.825 (0.219)	
Current living status			<0.001		<0.001		<0.001
Live alone	180 (23.5)	0.744 (0.268)		0.796 (0.240)		0.716 (0.279)	
Live with family	453 (59.2)	0.834 (0.225)		0.829 (0.238)		0.838 (0.216)	
Others	132 (17.3)	0.608 (0.331)		0.610 (0.333)		0.606 (0.239)	
Monthly income (¥)			0.117		0.115		0.384
<1,000	264 (34.5)	0.751 (0.283)		0.721 (0.299)		0.768 (0.273)	
1,001–3,000	198 (25.9)	0.806 (0.275)		0.824 (0.275)		0.795 (0.276)	
3,001–5,000	194 (25.4)	0.761 (0.248)		0.772 (0.245)		0.751 (0.251)	
>5,001	109 (14.2)	0.795 (0.260)		0.776 (0.292)		0.824 (0.198)	
Number of chronic diseases			<0.001		<0.001		<0.001
1	172 (22.5)	0.869 (0.223)		0.879 (0.218)		0.860 (0.229)	
2	225 (29.4)	0.808 (0.260)		0.818 (0.251)		0.800 (0.266)	
≥3	368 (48.1)	0.709 (0.279)		0.691 (0.297)		0.724 (0.263)	
Smoking			0.941		0.806		0.899
Yes	553 (72.3)	0.774 (0.275)		0.766 (0.293)		0.777 (0.268)	
No	212 (27.7)	0.775 (0.255)		0.774 (0.266)		0.783 (0.196)	
Alcohol			0.001		0.002		0.105
Yes	584 (76.3)	0.757 (0.284)		0.730 (0.309)		0.770 (0.269)	
No	181 (23.7)	0.830 (0.209)		0.827 (0.218)		0.840 (0.178)	
Sleep schedule (h)			0.001		0.018		0.032
<6	246 (32.2)	0.775 (0.256)		0.770 (0.281)		0.782 (0.240)	
6–8	356 (46.5)	0.803 (0.244)		0.807 (0.238)		0.801 (0.249)	
>8	163 (21.3)	0.705 (0.327)		0.701 (0.332)		0.709 (0.323)	

SC, UA, PD, and AD. The percentage of female n is generally higher than that of male in all five dimensions. Age and number of chronic diseases affect the four dimensions of MO, SC, UA, and PD. The presence of or having a spouse, current living status, and monthly income affected the three dimensions of MO, SC, and UA, respectively. Education is a factor that influences both SC and UA dimensions. Sleep schedule is a factor that influences both PD and AD dimensions.

The OLS model is used to analyze the factors influencing each variable on the utility scores. The results of the study show that younger (60–70: beta = 0.106,95% CI = 0.059–0.154, 70–80:

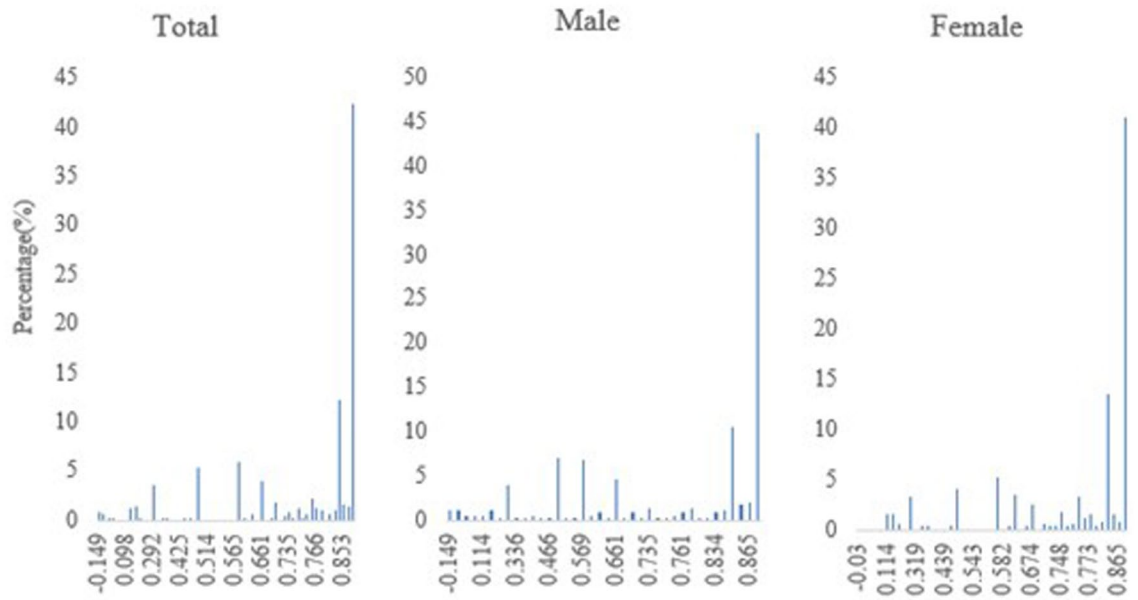

FIGURE 2
The distribution of EQ-5D-3L scores for total, and stratified by male and female.

beta = 0.075,95% CI = 0.027–0.123), having a spouse (beta = 0.063,95% CI = 0.014–0.112), financial independence (pension: beta = 0.069,95% CI = 0.017–0.122, other: beta = 0.103,95% CI = 0.050–0.155), living with family (beta = 0.119,95% CI = 0.048–0.190) and number of one chronic disease (beta = 0.043,95% CI = 0.001–0.084) were protective factors affecting health utility scores. Illiteracy (beta = −0.075, 95% CI = −0.137 to −0.138) and the number of three or more chronic diseases (beta = −0.070, 95% CI = −0.111 to 0.028) are the risk factors affecting health utility. See Table 4.

4 Discussion

To the best of our knowledge, this was the first study to evaluate the health quality of life and its associated factors among older adults with cardiovascular disease in eastern China. EQ-5D instrument has been widely used in pharmacoeconomic analysis and the evaluation of health policy program as a consistent and transparent measurement of the output of health care and public health system (28). Further, our study identified factors associated with HRQoL that could be targeted by interventions to improve patients' HRQoL and reduce burden of the disease.

Our findings demonstrated that CVD diagnosis was significantly associated with impaired HRQoL. The study results show that this target population scores 0.774, which is much lower than the HRQoL in the general population (0.959) (29). Aya Barham et al. (30) scored 0.62 on the EQ-5D for people with cardiovascular disease (one type of disease) in Nablus, Palestine, which is much lower than the results of this study. These differences in utility values could be due to variations in patients' profiles, sociocultural beliefs, and types of CVD across study settings as well as access to medical care and differences in EQ-5D-3L tariffs utilized.

Among older adults with CVD, females report slightly higher scores than males. This differs from the Korean study of the older adults, which found lower scores for females than for male (31). This may be due to the different study subjects, with the Korean study targeting all older adults and the current research focusing on older adults with CVD. In addition to this, compared to Korea, female respondents were younger than males in the estimation of the relative factors in this study, which may have resulted in the gender difference in this study being offset by the age difference. This may also be related to the level of education, which was significantly higher in the present study population than in Korea, and women were more educated than men, and sick women with higher education were more aware of healthy lifestyles, which had an impact on health-related quality of life.

The relationship between sleep and HRQOL has been studied. Short sleep may impair cognitive function, increase fatigue, and increase the risk of chronic diseases such as diabetes, obesity, and hypertension, leading to a poorer quality of life (32). In addition to this, the current study also finds an effect of sleep schedule on PD and AD, and there is no detailed study in Chen-Wei Pan and Sujeong Mun's et al. (31) analysis showing the effect of sleep schedule on the dimensions of the scale, which is a relative improvement in the present study.

The results of the study show that age and number of chronic diseases were the key factors affecting the HRQoL score and the four dimensions of MO, SC, UA, and PD. This is similar to previous studies in that older adults have longer disease duration, the decline of HRQoL with older individuals could be attributed to increased deterioration of physical functioning, which might increase CVD progression and non-cardiac comorbidities leading to reduced overall HRQoL (33, 34). Financially independent (pension and other sources of income) older adults with CVD have relatively higher health indices. These are similar to existing research findings (21, 35). Financial independence also had a positive effect on five dimensions of EQ-5D-3L, which is similar to the findings of Li et al. (36). It can be assumed that differences in living environments, according to socioeconomic status, cause gaps among social classes in the quality

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TABLE 3 Proportion of EQ-5D-3L reporting any problems in five dimensions.

Variable	Mobility		Self-care		Usual activities		Pain/discomfort		Anxiety/depression	
	n (%)	*p*	*n* (%)	*p*	*n* (%)	*p*	*n* (%)	*p*	*n* (%)	*p*
Overall	275 (35.9)		241 (31.5)		277 (36.2)		306 (40.0)		130 (17.0)	
Gender		0.324		0.050	129 (38.2)	0.316		0.035		0.637
Male	128 (37.9)		119 (35.2)		148 (34.7)		121 (35.8)		55 (16.3)	
Female	147 (34.4)		122 (28.6)		277 (36.2)		185 (43.3)		75 (17.6)	
Age (years)		<0.001		<0.001		<0.001		<0.001		0.009
60–70	43 (16.3)		38 (14.4)		46 (17.5)		77 (29.3)		30 (11.4)	
70–80	64 (31.2)		58 (28.3)		67 (32.7)		88 (42.9)		38 (18.5)	
>80	168 (56.6)		145 (48.8)		164 (55.2)		141 (47.5)		62 (20.9)	
Spouse		<0.001		<0.001		<0.001		0.538		0.097
Yes	132 (26.9)		109 (22.2)		129 (26.3)		192 (39.2)		75 (15.3)	
No	143 (52.0)		132 (48.0)		148 (53.8)		114 (41.5)		55 (20.0)	
Education		<0.001		0.001		<0.001		0.1661		0.369
Illiteracy	102 (45.7)		89 (39.9)		102 (45.7)		103 (46.2)		46 (20.6)	
Primary school	91 (37.3)		82 (33.6)		93 (38.1)		93 (38.1)		38 (15.6)	
Junior high school	41 (27.0)		36 (23.7)		43 (28.3)		57 (37.5)		22 (14.5)	
High school and above	41 (28.1)		34 (23.3)		39 (26.7)		53 (36.3)		24 (16.4)	
Financial resources		<0.001		<0.001		<0.001		<0.001		0.008
Pension	135 (32.3)		123 (29.4)		139 (33.3)		153 (36.6)		69 (16.5)	
Support from family and friends	96 (50.8)		83 (43.9)		96 (50.8)		101 (53.4)		44 (23.3)	
Others	44 (27.8)		35 (22.2)		42 (26.6)		52 (32.9)		17 (10.8)	
Current living status		<0.001		<0.001		<0.001		0.812		0.049
Live alone	79 (43.9)		63 (35.0)		78 (43.3)		72 (40.0)		29 (16.1)	
Live with family	118 (26.0)		95 (21.0)		113 (24.9)		178 (39.3)		69 (15.2)	
Others	78 (59.1)		83 (62.9)		86 (65.2)		56 (42.4)		32 (24.2)	
Monthly income (¥)		0.015		0.020		0.004		<0.001		0.100
<1,000	98 (37.1)		79 (29.9)		97 (36.7)		132 (50.0)		55 (20.8)	
1,001–3,000	55 (27.8)		52 (26.3)		55 (27.8)		63 (31.8)		29 (14.6)	
3,001–5,000	84 (43.3)		78 (40.2)		88 (45.4)		72 (37.1)		25 (12.9)	
>5,001	38 (34.9)		32 (29.4)		37 (33.9)		39 (35.8)		21 (19.2)	
Number of chronic diseases		<0.001		<0.001		<0.001		<0.001		0.016
1	37 (21.5)		35 (20.3)		39 (22.7)		39 (22.7)		18 (10.5)	
2	65 (28.9)		53 (23.6)		61 (27.1)		79 (35.1)		37 (16.4)	
≥3	173 (47.0)		153 (41.6)		177 (48.1)		188 (51.1)		75 (20.4)	
Smoking		0.099		0.464		0.707		0.843		0.520
Yes	189 (34.2)		170 (30.7)		198 (35.8)		220 (39.8)		91 (16.5)	
No	86 (40.6)		71 (33.5)		79 (37.3)		86 (40.6)		39 (18.4)	
Alcohol		0.021		0.017		0.010		0.199		0.079
Yes	223 (38.2)		197 (33.7)		226 (38.7)		241 (41.3)		107 (18.3)	
No	52 (28.7)		44 (24.3)		52 (28.2)		65 (35.9)		23 (12.7)	
Sleep schedule (h)		0.248		0.169		0.058		0.041		<0.001
<6	91 (37.0)		76 (30.9)		83 (33.7)		113 (45.9)		52 (21.1)	
6–8	118 (33.1)		104 (29.2)		122 (34.3)		127 (35.7)		40 (11.2)	
>8	66 (40.5)		61 (37.4)		72 (44.2)		66 (40.5)		38 (23.3)	

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TABLE 4 A binary logistic and OLS regression model of responses to the EQ-5D for total.

	Mobility		Self-care		Usual activities		Pain/ discomfort		Anxiety/ depression		HRQoL score	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	beta	95% CI
Age (years)												
>80	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
60–70	0.226*	0.142,0.361	0.302*	0.185,0.493	0.291*	0.182,0.466	0.501*	0.328,0.765	0.687	0.398,1.187	0.106*	0.059,0.154
70-80	0.391*	0.255,0.601	0.482*	0.308,0.753	0.476*	0.308,0.736	0.846	0.565,1.265	1.002	0.611,1.643	0.075*	0.027,0.123
Spouse												
No	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Yes	0.519*	0.341,0.791	0.440*	0.284,0.682	0.464*	0.303,0.710	1.157	0.776,1.724	0.885	0.544,1.439	0.063*	0.014,0.112
Education												
High school and above	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Illiteracy	1.778	0.952,3.317	2.113*	1.095,4.078	2.116*	1.120,4.001	1.006	0.574,1.763	0.905	0.446,1.834	−0.075*	−0.137,-0.138
Primary school	1.506	0.850,2.667	1.669	0.915,3.043	1.738	0.971,3.112	0.843	0.508,1.399	0.822	0.431,1.570	−0.025	−0.080,0.030
Junior high school	1.158	0.639,2.099	1.187	0.635,2.218	1.319	0.724,2.403	1.240	0.744,2.068	1.011	0.518,1.974	−0.006	0.053,0.042
Financial resources												
Support from family and friends	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Pension	0.423*	0.265,0.674	0.562*	0.347,0.909	0.483*	0.301,0.774	0.609*	0.400,0.929	0.885	0.529,1.483	0.069*	0.017,0.122
Others	0.433*	0.251,0.746	0.384*	0.212,0.695	0.391*	0.222,0.687	0.431*	0.265,0.701	0.393*	0.206,0.750	0.103*	0.050,0.155
Current living status												
Others	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Live alone	0.596	0.347,1.024	0.260*	0.148,0.456	0.412*	0.237,0.714	1.203	0.718,2.015	0.683	0.367,1.269	0.104*	0.032,0.176
Live with family	0.524*	0.317,0.866	0.274*	0.164,0.459	0.352*	0.211,0.587	1.292	0.801,2.083	0.679	0.384,1.203	0.119*	0.048,0.190
Monthly income (¥)												
>5,001	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
<1,000	0.438*	0.231,0.832	0.384*	0.196,0.754	0.417*	0.218,0.798	1.839*	1.031,3.281	1.148	0.560,2.354	0.043	−0.021,0.109
1,001–3,000	0.480*	0.258,0.890	0.556	0.292,1.057	0.458*	0.244,0.859	0.935	0.537,1.629	0.792	0.397,1.580	0.034	−0.029,0.097
3,001–5,000	1.661	0.934,2.955	1.874*	1.031,3.407	1.802*	1.009,3.222	1.020	0.601,1.732	0.644	0.327,1.266	−0.042	−0.06,0.127
Number of chronic diseases												
2	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
1	0.794	0.468,1.348	0.980	0.561,1.711	0.882	0.516,1.507	0.594*	0.371,0.950	0.654	0.349,1.224	0.043*	0.001,0.084
≥3	2.056*	1.374,3.074	2.176*	1.419,3.338	2.386*	1.580,3.602	1.879*	1.308,2.698	1.188	0.750,1.882	−0.070*	−0.111,0.028
Alcohol												
No	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Yes	0.956	0.622,1.468	0.950	0.606,1.489	0.915	0.594,1.410	1.004	0.684,1.473	0.815	0.484,1.374	0.017	−0.019,0.052
Sleep schedule (h)												
<6	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
6–8	0.068	0.455,1.022	0.702	0.459,1.074	0.839	0.556,1.265	0.694*	0.484,0.995	0.480*	0.299,0.769	0.033	−0.004,0.070
>8	0.877	0.537,1.432	0.962	0.579,1.598	1.286	0.784,2.109	0.716	0.457,1.121	0.954	0.568,1.604	−0.036	−0.090,0.018

*$p < 0.05$.

of information available and the healthcare system. Therefore, if customized patient interventions are developed considering differences in financial independence, patients' HRQOL may be improved.

We observe that the reduction in the HRQoL scores is strongly associated with having problems in the pain dimension (PD) in patients with CVD. These findings were in line with previous studies in other regions (21, 37, 38). In a study in Thailand, it was found that 50% of people with diabetes had PD problems (39). It has also been noted that the intensity of pain can affect HRQoL (37). Therefore, there is a need to focus on pain in the older adults caused by cardiovascular disease and discuss various pain reduction methods with clinical staff. This study utilizes different sociodemographic characteristics of EQ-5D-3L to provide a reference for HRQoL scores of Chinese older adults with CVD. Those results are essential in informing policies to improve CVD treatment and health outcomes and promote regional and interstate planning of CVD services.

Moreover, in the older adults, to overcome the ceiling effect and some other characteristics of the EQ-5D data, different regression models are applied to ensure the validity and robustness of the estimates when exploring the relationship between CVD and HRQoL. Although the study results show that the results of the OLS model were more accurate, further research is needed to test different populations using other methods.

5 Limitation

There are some limitations to this study. First, since our study was a cross-sectional survey, it is not possible to demonstrate causal relationships between associated factors and HRQoL. Second, patients were recruited from the eastern part of the country, and thus, our conclusions cannot be generalized to CVD patients in Chinese. It is suggested that future studies should consider expanding the sample to include more geographic areas in order to gain a more comprehensive understanding of the impact of economic factors on health-related quality of life (HRQoL) in older patients with cardiovascular disease. Thirdly, there is no specific EQ-5D norm for the oldest-old Chinese population, thus we adopted the TTO value set for the overall Chinese population. At the same time EQ-5D-3L as a simplified version of EQ-5D-5L, the limitations of specific own application defects. Further studies could be dedicated to develop the EQ-5D norm for this population to better understand their self-reported quality of life.

6 Conclusion

We find that the HRQoL of Chinese older adults with CVD is not high (0.774). Age, number of chronic diseases, financial independence, and sleep schedule all affected HRQoL, and the PD dimension of the EQ-5D-3L has a significant effect on HRQoL scores. Therefore, future intervention efforts aimed at improving HRQoL in CVD patients should be designed with a focus on modifiable factors such as controlling progression of CVD and revention, treatment of chronic diseases and improving sleep quality. PD relief can be explored with clinical professionals for patients with pain problems. These inform the provision of targeted services for older adults with CVD. Further research is needed to determine whether these estimates are consistent across different types of older adults with CVD or other diseases.

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 this study was consistent with "Zhengzhou University Life Science Ethics Committee" [Ethics approval code ZZUIRB2022-07]. Participants were required to provide informed consent. 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

LW: Data curation, Writing – original draft, Writing – review & editing. GY: Conceptualization, Data curation, Methodology, Writing – original draft. HD: Formal analysis, Methodology, Writing – original draft. XL: Methodology, Project administration, Writing – original draft. YH: Funding acquisition, Writing – review & editing.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1300404/full#supplementary-material

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Factors affecting advance directives completion among older adults in Korea

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Objective: Advance directives (ADs) provide an opportunity for patients to enhance the quality of their end-of-life care and prepare for a dignified death by deciding treatment plans. The purpose of this study was to explore the multiple factors that influence the advance directives completion among older adults in South Korea.

Methods: This was a secondary analysis of a cross-sectional study of 9,920 older adults. The differences in ADs based on subjects' sociodemographic characteristics, health-related characteristics, and attitude toward death were tested using the chi-squared and *t*-test. A multinomial logistic regression model was used to identify the influencing factor of ADs.

Results: The number of chronic diseases, number of prescribed medications, depression, insomnia, suicide intention, and hearing, vision, or chewing discomfort were higher in the ADs group compared to the non-ADs group. The influencing factors of the signing of ADs included men sex, higher education level, exercise, death preparation education, lower awareness of dying-well, and experience of fracture.

Conclusion: Information dissemination regarding ADs should be promoted and relevant authorities should consider multiple options to improve the physical and psychological health of older adults, as well as their attitude toward death to increase the ADs completion rate.

KEYWORDS

advanced directives, dying-well, advanced care planning, aged, end of life

1 Introduction

Since 2017, Korea has become an aged society, with the proportion of the population aged 65 or above exceeding 14% (1). With the rapid aging of the population, the support for older adults, which was the traditional function of the family, has weakened. Studies have revealed that many individuals die after receiving life-sustaining treatment and care for an extended period in various care settings, such as nursing facilities, nursing hospitals, and acute care hospitals (2, 3). According to a 2022 report, 14.9% of older adults aged 65 or above died at home, and 76.4% died in medical institutions including nursing hospitals (4).

The concept of dying-well refers to a dynamic and continuous process in which patients, their families, and medical staff interact to fulfill patients' wishes during the end-of-life preparations (5). The family interactions include avoidance of futile prolongation of life, death with dignity and comfort, and experiencing positive feelings with the family (5). In a previous

study conducted in the Republic of Croatia, the presence of family and loved ones was also a significant affecting factor in the good death (6).

Advance directives (ADs) are a significant component of life-care planning. They are legal documents through which a person aged 19 or above with decision-making ability makes a written decision in advance about the medical treatment to be received in the future according to his/her own values after being provided sufficient information through an advance directive on life-sustaining treatment (7). ADs were developed by an American lawyer, Luis Kutner to make a legal statement about one's healthcare, much like about one's wealth and property (8). ADs have dramatically evolved over time, comprising the living will, Durable Power of Attorney, Do Not Resuscitate forms, and Medical Orders for Sustaining Treatment (9, 10).

ADs were introduced as an opportunity for patients to enhance the quality of their end of-life care and prepare for a dignified death by discussing and deciding treatment plans with their families and medical staff (11). Owing to these advantages, one in three US adults have documented their ADs (12). In February 2018, the Act on Decisions on Hospice Palliative Care and Life-Sustaining Treatment for Patients in the Ending Process was enforced in Korea. However, seven out of 10 cases of withholding or discontinuing life-sustaining treatment in Korea are family decisions (13). Even in the West, where ADs were early legislated, it has been reported that the completion of ADs remains a social, cultural, and ethical dilemma so it should be utilized effectively (14). In Korea, which is a family-oriented culture, the factors that influence the completion of ADs, which is a legislated form, may be different from those in the West (15).

In Korea, ADs introduction and research are in the early stages. Existing studies have mainly explored the knowledge, attitude, and intention toward the medical staff or ADs of adults. Moreover, the entities responsible for registering advance directives for life-sustaining treatment in Korea include medical institutions, non-profit organizations, and public institutions. Consequently, the adequacy of the agency's obligation to provide explanations may be insufficient when individuals are preparing an advance directive for life-sustaining treatment (16). Knowledge about life-sustaining care was the most influential factor affecting the intention to complete ADs (17). However, other factors also play a role, including demographic and socioeconomic factors (e.g., age, religion, education, and economic level), physical health-related factors (presence of chronic or critical diseases, subjective health status), awareness of dying-well, and attitude toward Ads. These factors have all been shown to affect the ADs completion (17–19). According to a previous study, the fear that discussing AD itself might signal patients to give up hope could be a key reason healthcare providers delay important conversations (20). Contrary to concerns, empirical research has shown that completing ADs does not decrease hope in patients; notably, it has been observed to increase hope (21). While multiple factors influence ADs completion, comprehensive studies have been relatively scarce.

2 Objective

Therefore, this study aimed to explore the factors influencing ADs completion among older adults in Korea. This study assumed that general characteristics, physical health-related characteristics, psychological characteristics, and attitudes toward death would significantly impact the ADs completion among older adults in Korea.

3 Materials and methods

3.1 Study design

This study was a secondary analysis of the data from a previous cross-sectional study that explored the influencing factors of ADs among older adults living in the community.

3.2 Data collection and participants

This study analyzed the cross-sectional nationwide data obtained from the 2020 National Survey of Older Koreans, which is conducted every 3 years by the Korean Ministry of Health and Welfare. The 2020 original survey data were collected by 169 trained interviewers using the Tablet-PC Assisted Personal Interview (TAPI) method from September 14 to November 20, 2020. The interviewers selected were individuals experienced in conducting similar surveys. Furthermore, training was provided six times (22). This study was conducted via face-to-face interviews. The target population comprised older adults (65 years or above) who lived in communities in 17 cities and provinces across the country. The 2020 National Survey of Older Koreans sample was selected using a proportional two-stage stratified sampling method. First, the population was stratified by 17 metropolitan cities and provinces across Korea, and thereafter, re-stratified by neighborhood in the nine provinces (but not in the seven metropolitan cities). The Ministry of Health and Welfare research team applied various weights in the raw data to ensure the accuracy of estimations. The weight of the raw data was adjusted by considering the weights for households and individuals (22). The study population represented Korean older adults aged 65 years living in the community. Of the total 10,097 respondents from the 2020 National Survey of Older Koreans, 9,920 were selected; 167 were excluded because they comprised proxy respondents and 10 were excluded because of missing responses. The researchers received coded data, which were used for secondary data analysis.

3.3 Ethical considerations

The 2020 National Survey of Older Koreans was approved by Statistics Korea (Approval No. 117071). The institutional review board approval was obtained from the Korea Institute for Health and Social Affairs (IRB No. 2020–36) prior to conducting the survey. All participants provided written informed consent prior to participation and were informed that they could withdraw their consent at any time without any disadvantage. After obtaining approval for our study, we received the raw data without personal identification information. Additionally, the study was approved by the Institutional Review Board of G University (IRB No. 1044396-202202-HR-039-01)—the corresponding author is affiliated with this university. All methods were applied in accordance with the relevant guidelines and regulations.

3.4 Measurements

3.4.1 ADs

ADs were measured using the question, "Did you complete an AD in preparation for death at the end of your life?" The response options were: 1 = yes, 2 = no.

3.4.2 Sociodemographic characteristics

General characteristics (e.g., age, sex, spouse, spouse health status, religion, and education level) were self-reported.

3.4.3 Physical-health-related characteristics

Physical-health-related characteristics included the presence of chronic diseases (e.g., number of diagnosed chronic diseases, medication, used medical institution, etc.), alcohol intake (frequency for 1 year), smoking (yes or no), nutritional status, body mass index (BMI), activities of daily living (ADL), instrumental activities of daily living (IADL), exercise (yes or no), muscle power, and sensory discomfort (feeling in daily life: comfortable, a little uncomfortable, and uncomfortable). Moreover, fall experience for 1 year (yes or no) was estimated.

Nutritional status was investigated using a nutritional screening initiative checklist (23). This tool comprised 10 items, and the total score was calculated out of 21 points by weighting each item. The subjects were instructed to sit on a chair or bed and then stand up five times, and the muscle power was evaluated as: performed, failed, impossible to perform, and rejected. Additionally, sensory discomforts such as hearing, vision, and chewing difficulties were investigated.

3.4.4 Psychological characteristics

Psychological characteristics including depression, cognitive function, subjective satisfaction (health, economy, and overall), suicide intention, and social relationship (number of friends or neighborhood) were self-reported. Depression was estimated using the Korean version of the short form of the Geriatric Depression Scale (SGDS-K) (24), and cognitive function was estimated using the Korean version of the Mini-Mental State Examination for dementia screening (KMMSE-DS) (25).

3.4.5 Attitude toward death

Attitude toward death included the attitude toward medical care for life prolongation, death preparation education (yes or no), and awareness of dying-well. The awareness of the significance of dying-well at the end of life among the older adult was estimated by adding the total of four items: preparing for dying by oneself, dying without pain, dying in the presence of family or close friends, and dying that is not a burden to family or close friends. These items were rated on a 5-point Likert scale. The lower the total score, the higher the awareness of the significance of dying-well.

3.5 Data analysis

The collected data were analyzed using the SPSS Win 23.0 program (SPSS, IBM Corp., Armonk, NY, United States), with the two-tailed significance level set at 0.05. The items "not applicable" and "not respond" replies were excluded from the final analysis. Differences in participants' characteristics based on ADs completion were examined with a t-test or chi-squared test. Furthermore, the multinomial logistic regression analysis was performed to identify the predictive factors of complete ADs.

4 Results

4.1 Differences in subjects' characteristics based on the advance directives completion

Spouse health status with a somewhat unhealthy or unhealthy state ($p = 0.018$) and religion ($p = 0.017$) were significantly prevalent in the ADs group compared to the non-ADs group. The education level was higher in the ADs group than in the non-ADs group ($p < 0.001$; Table 1). The number of chronic diseases, number of prescription medications, frequency of alcohol consumption for 1 year, nutritional status, and frequency of exercise were higher in the ADs group than in the non-ADs group ($p < 0.001$, $p < 0.001$, $p = 0.004$, $p = 0.006$, and $p = 0.04$, respectively; Table 1). Compared to the non-ADs group, the ADs group had weaker muscle power, a higher degree of depression, more disagreement with medical care for life prolongation, higher death preparation education experience, lower awareness of dying-well, and a higher level of suicide intention ($p = 0.043$, $p = 0.004$, $p < 0.001$, $p < 0.001$, $p = 0.004$, and $p < 0.001$, respectively; Table 1). Regarding the comparison of the details of dying-well awareness, the older adults in the non-ADs group considered dying without pain, dying in the presence of family or close friends, and dying that is not a burden to them as more significant than those in the ADs group ($p = 0.032$, $p = 0.006$, and $p = 0.001$, respectively; Table 1).

4.2 Differences in subjects' diagnosed chronic diseases based on the advance directives completion

The prevalence rate of diabetes mellitus (DM) was lower in the ADs group than in the non-ADs group ($p < 0.010$). The fracture experience and prevalence rate of insomnia were higher in the ADs group than in the non-ADs group ($p = 0.024$ and $p = 0.003$, respectively). The prevalence rate of cataracts and fall experience for 1 year was higher in the ADs group than in the non-ADs group ($p = 0.003$ and $p = 0.002$, respectively; Table 2).

4.3 Differences in sensory discomfort based on the advance directives completion

The rate of feeling a little uncomfortable in terms of hearing, vision, or chewing was higher in the ADs group than in the non-ADs group ($p = 0.010$, $p = 0.001$, and $p = 0.036$, respectively; Table 3).

4.4 Associated factors of the advance directives completion

A multiple logistic regression analysis was conducted to examine the factors affecting the advance directives completion. The analysis included variables with significant differences in the

TABLE 1 Differences in subjects' characteristics based on the signing of advance directives ($N = 9,920$).

Categories	Variable		ADs group ($N = 421$) Mean ± SD/N(%)	Non-ADs group ($N = 9,499$) Mean ± SD/N(%)	t/χ^2	p
General characteristics	Age		73.80 ± 6.33	73.42 ± 6.54	1.147	0.251
	Sex	Men	207 (49.2)	3,764 (39.6)	15.295	<0.001
	Spouse	Yes	262 (62.2)	5,586 (58.8)	1.956	0.172
	Spouse health status	Very healthy	15 (5.7)	329 (5.9)	11.936	0.018
		Healthy	149 (56.9)	2,960 (53.0)		
		Moderate	53 (20.2)	1,569 (28.1)		
		Somewhat unhealthy	35 (13.4)	621 (11.1)		
		Unhealthy	10 (3.8)	107 (1.9)		
	Religion (Yes)	Yes	272 (64.6)	5,578 (58.7)	5.773	0.017
	Education level		9.11 ± 4.10	8.15 ± 3.99	4.827	<0.001
Physical-health-related characteristics	No. of chronic diseases		2.09 ± 1.58	1.82 ± 1.46	3.648	<0.001
	No. of prescription medications		2.05 ± 1.63	1.76 ± 1.53	3.781	<0.001
	Use of medical institutions		298 (70.8)	6,531 (68.8)	0.774	0.390
	Drinking alcohol		1.42 ± 1.88	1.14 ± 1.75	2.926	0.004
	Smoking	Yes	48 (11.4)	1,041 (11.0)	0.081	0.750
	Nutritional status		22.53 ± 1.65	22.76 ± 1.69	−2.772	0.006
	BMI		23.47 ± 2.73	23.58 ± 2.59	−0.816	0.415
	ADL		7.23 ± 1.20	7.17 ± 1.09	0.958	0.338
	IADL		10.69 ± 2.88	10.60 ± 2.58	0.647	0.518
	Exercise	Yes	245 (58.2)	4,942 (52.0)	6.148	0.014
	Muscle power	Performed	310 (73.6)	6,975 (73.4)	8.142	0.043
		Fail	77 (18.3)	1902 (20.0)		
		Impossible to perform	16 (3.8)	180 (1.9)		
		Reject	18 (4.3)	442 (4.7)		
Psychological characteristics	Depression		3.84 ± 3.35	3.35 ± 3.40	2.888	0.004
	Cognitive function		24.29 ± 6.59	24.32 ± 5.25		
	Subjective satisfaction (Health)	Very satisfied	23 (5.5)	441 (4.6)	3.086	0.544
		Satisfied	208 (49.4)	4,540 (47.8)		
		Somewhat	113 (26.8)	2,897 (30.5)		
		Unsatisfied	67 (15.9)	1,385 (14.6)		
		Not at all	10 (2.4)	236 (2.5)		
	Subjective satisfaction (economy)	Very satisfied	33 (7.8)	706 (7.4)	10.272	0.036
		Satisfied	159 (37.8)	2,994 (31.5)		
		Somewhat	168 (39.9)	3,968 (41.8)		
		Unsatisfied	53 (12.6)	1,611 (17.0)		
		Not at all	8 (1.9)	220 (2.3)		
	Subjective satisfaction (overall)	Very satisfied	21 (5.0)	397 (4.2)	2.799	0.592
		Satisfied	207 (49.2)	4,515 (47.5)		
		Somewhat	170 (40.4)	3,899 (41.0)		
		Unsatisfied	22 (5.2)	644 (6.8)		
		Not at all	1 (0.2)	44 (0.5)		
	Suicide intention	Yes	19 (4.5)	168 (1.8)	16.417	<0.001
	Social relationship		2.86 ± 2.41	3.05 ± 2.56	−1.512	0.131
Attitude toward death	Attitude toward medical care for life prolongation	Very agree	0 (0.0)	9 (0.1)	20.873	<0.001
		Agree	0 (0.0)	221 (2.3)		
		Somewhat	44 (10.5)	1,081 (11.4)		
		Disagree	201 (47.7)	3,703 (39.0)		
		Very disagree	176 (41.8)	4,485 (47.2)		

(Continued)

TABLE 1 (Continued)

Categories	Variable		ADs group ($N = 421$) Mean ± SD/N(%)	Non-ADs group ($N = 9,499$) Mean ± SD/N(%)	t/χ^2	p
	Take death preparation education	Yes	63 (15.0)	206 (2.2)	250.194	<0.001
	Awareness of well-dying	Total	7.02 ± 2.19	6.70 ± 2.18	2.915	0.004
	(1) Prepare for dying by oneself	Very important	163 (38.7)	3,661 (38.5)	0.533	0.970
		Important	211 (50.1)	4,738 (49.9)		
		Somewhat	43 (10.2)	981 (10.3)		
		Not important	4 (1.0)	111 (1.2)		
		Not at all	0 (0.0)	8 (0.1)		
	(2) Dying without pain	Very important	215 (51.1)	5,217 (54.9)	10.560	0.032
		Important	148 (35.2)	3,399 (35.8)		
		Somewhat	52 (12.4)	795 (8.4)		
		Not important	6 (1.4)	80 (0.8)		
		Not at all	0 (0.0)	8 (0.1)		
	(3) Dying in the presence of family or close friends	Very important	133 (31.6)	3,787 (39.9)	14.478	0.006
		Important	216 (51.3)	4,425 (46.6)		
		Somewhat	63 (15.0)	1,108 (11.7)		
		Not important	7 (1.7)	162 (1.7)		
		Not at all	2 (0.5)	17 (0.2)		
	(4) Dying that is not a burden to family or close friends	Very important	153 (36.3)	4,285 (45.1)	18.258	0.001
		Important	214 (50.8)	4,310 (45.4)		
		Somewhat	54 (12.8)	854 (9.0)		
		Not important	0 (0.0)	46 (0.5)		
		Not at all	0 (0.0)	4 (0.0)		

ADs, advance directives; SD, standard deviation; No, number; BMI, body mass index; ADL, activity daily living; IADL, instrumental activity daily living.

TABLE 2 Differences in subjects' diagnosed chronic diseases based on the signing of advance directives ($N = 9,920$).

Variable	ADs group ($N = 421$) N(%)	Non-ADs group ($N = 9,499$) N(%)	χ^2	p
Stroke (Yes)	14 (3.3)	372 (3.9)	0.376	0.698
Dyslipidemia (Yes)	85 (20.2)	1,604 (16.9)	3.115	0.085
Angina or MI (Yes)	24 (5.7)	425 (4.5)	1.403	0.230
CHF or Arrhythmia (Yes)	21 (5.0)	430 (4.5)	0.198	0.632
DM (Yes)	79 (18.8)	2,297 (24.2)	6.494	0.010
Fracture (Yes)	11 (2.6)	117 (1.2)	6.037	0.024
COPD (Yes)	5 (1.2)	115 (1.2)	0.002	1.000
Asthma (Yes)	10 (5.7)	165 (1.7)	0.948	0.339
Depression (Yes)	6 (1.4)	131 (1.4)	0.006	0.831
Parkinson (Yes)	4 (1.0)	44 (0.5)	1.985	0.145
Insomnia (Yes)	17 (4.0)	170 (1.8)	11.018	0.003
Cataract (Yes)	34 (8.1)	407 (4.3)	13.641	0.001
Cancer (Yes)	12 (2.9)	152 (1.6)	3.875	0.074
Fall experience for 1 year (Yes)	43 (10.2)	590 (6.2)	10.811	0.002

ADs, advance directives; MI, myocardial infarction; CHF, congestive heart failure; DM, diabetes mellitus; COPD, chronic obstructive pulmonary disease.

advance directives completion by univariate analysis (sex, religion, education level, number of chronic diseases, alcohol consumption frequency for 1 year, nutritional status, depression, subjective satisfaction with the economy, attitude toward medical care for life prolongation, awareness about dying-well, DM, fracture, insomnia, fall experience over 1 year, death preparation education, suicide intention, vision discomfort, hearing discomfort, and chewing discomfort). Before the analysis, the Hosmer and Lemeshow test was conducted to identify the goodness of fit. Our model could be considered reasonably good because $p = 0.455$. The associated factors of the advance directives completion included men, higher education level, exercise, death preparation education, lower

TABLE 3 Differences in sensory discomfort based on the signing of advance directives ($N = 9,920$).

Variable		ADs group ($N = 421$) N(%)	Non-ADs group ($N = 9,499$) N(%)	χ^2	p
Hearing	Comfortable	313 (74.3)	7,310 (77.0)	9.232	0.010
	A little uncomfortable	106 (25.2)	1986 (20.9)		
	Uncomfortable	2 (0.5)	203 (2.1)		
Vision	Comfortable	248 (58.9)	6,386 (67.2)	13.154	0.001
	A little uncomfortable	164 (39.0)	2,911 (30.6)		
	Uncomfortable	9 (2.1)	202 (2.1)		
Chewing	Comfortable	254 (60.3)	5,915 (62.3)	6.631	0.036
	A little uncomfortable	158 (37.5)	3,178 (33.5)		
	Uncomfortable	9 (2.1)	406 (4.3)		

ADs, advance directives.

awareness of dying-well, and experience of fracture ($p = 0.003$, $p = 0.009$, $p = 0.036$, $p < 0.001$, $p = 0.001$, $p = 0.004$, respectively; Table 4). Moreover, the odds ratio of completion of advance directives was significantly lower among participants with DM or moderate health spouses compared to those with very unhealthy spouses ($p = 0.001$, and $p = 0.015$, respectively; Table 4).

5 Discussion

In Korea, the proportion of older adult is rapidly increasing because of the low birth rate, the aging population, and improvement of medical technology (26). Although the average lifespan has increased, new challenges are emerging—for example, burden on individuals and society because of life-sustaining treatment which only prolongs the process of dying for the older adults with no possibility of recovery (27). With increasing societal interest in patient autonomy and a dignified and comfortable end of life, ADs for life-sustaining treatment were introduced in February 2018 to allow patients to end their lives with dignity (28).

From 2018 to 2021, a total of 194,181 cases were actually utilized of life-sustaining treatment plans for the entire population in Korea; however, only 7.5% of them were written by the patients themselves (29). The proportion of ADs signed by patients has been increasing every year since 2018. This study attempted to identify the ADs documentation rate in older people in Korea and investigate its influencing factors by using the data from the 2020 National Survey of Older Koreans (22).

The current ADs completion rate remains low at 4.24% among people aged 65 years and above. In some eastern countries, such as Japan, China and Hong Kong, advance directives are still very slowly being promoted, but they are not legally enforceable because people generally avoid talking about death because it is considered disrespectful (30, 31). The ADs documentation system is known to be effective in patient care (32), decreased healthcare cost and utilization (33), and decreased futile life-sustaining treatment (34). Nevertheless, even in the United States, where relevant legislation was enacted even earlier, the rate of completed ADs was reported to be 26% in 2009 and 2010 (35). Whites are more likely to complete AD than Blacks or Hispanics (36). Previous studies have shown that this is because racial/ethnic differences in complete AD are multifaceted, strongly influenced by a variety of cognitive and psychological, sociocultural, and sociodemographic factors (37). Taken together, race/ethnicity can be seen as a proxy for personal, cultural, and social contexts, so that an individual's values, beliefs, and personal circumstances are necessary for the completion of ADs.

This study investigated the factors affecting ADs documentation among older adults, including general characteristics, physical-health-related characteristics, psychological characteristics, and attitudes toward death. The significant factors that increase the ADs group's odds ratio compared to the non-ADs group included sex, education level, spousal health status, exercise, death preparation education, and fracture experience. The lowering factors included the absence of difficulty in chewing, presence of DM, and awareness of dying-well.

The ADs completion rates were 5.2% for men and 3.6% for women. The odds ratio for men to belong to the ADs group was higher than for women. This result contradicted the previous report that women had a higher ADs completion rate than men in all age groups in Korea (29). This discrepancy may be because the participants of this study included only the community-dwelling older adults with a high proportion of men and excluded the older adults in medical facilities (22). In a previous study among older Korean-American adults, sex was not a significant factor in ADs completion, even though ADs awareness was higher in women than men (38). Future research should examine the differences this study found by attempting to determine whether there are gender differences in ADs documentation, including among older adults admitted to facilities and hospitals.

The result that death preparation education is an influencing factor of ADs completion is consistent with the results of previous studies that reported that direct patient-healthcare professional interactions may be more effective than passive patient education materials (39). However, lower awareness of dying-well an influencing factor of ADs completion was an unexpected result. According to a previous study, people tend to make decisions based on the values and possibilities inherent in a specific situation (40). Another study found that awareness of ADs and higher education level were significant factor in ADs completion (37, 41). Although the number of registered agencies for advance directives are increasing (28), it is difficult to find an agency that helps older adult prepare for death. Therefore, efforts to increase the awareness of dying-well and the significance of end-of-life planning are required.

The number of chronic diseases, number of prescribed medications, depression, insomnia, and suicide intention were higher

TABLE 4 Associated factors of the signing of advance directives (N = 9,920).

Independent variable		*B*	*SE*	*p*	Adjusted OR	95% CI	
						Lower	Upper
Sex (men)		0.446	0.152	0.003	1.563	1.160	2.104
Spouse health status	Very healthy	−0.563	0.465	0.226	0.570	0.229	1.416
	Healthy	−0.552	0.371	0.137	0.576	0.278	1.191
	Moderate	−0.931	0.382	0.015	0.394	0.187	0.832
	Somewhat unhealthy	−0.576	0.395	0.146	0.562	0.259	1.221
Religion (No)		−0.112	0.138	0.419	0.894	0.682	1.172
Education level		0.052	0.020	0.009	1.053	1.013	1.096
No. of chronic diseases		0.078	0.078	0.318	1.081	0.928	1.259
No. of prescribed medications		0.067	0.058	0.249	1.070	0.954	1.199
Alcohol consumption fx for 1 year		−0.015	0.038	0.705	0.986	0.914	1.063
Nutritional status		−0.052	0.050	0.299	0.949	0.860	1.048
Exercise (Yes)		0.295	0.140	0.036	1.343	1.020	1.768
Depression		0.034	0.024	0.169	1.034	0.986	1.085
Subjective satisfaction (economy)	Very satisfied	−0.229	602	0.703	0.795	0.245	2.586
	Satisfied	−0.456	0.563	0.418	0.634	0.210	1.912
	Somewhat	−0.266	0.555	0.632	0.766	0.258	2.276
	Unsatisfied	−0.684	0.575	0.234	0.504	0.164	1.556
Attitude toward medical care for life prolongation	Very agree	−19.272	15896.291	0.999	0.000	0.000	.
	Agree	−18.849	3410.416	0.996	0.000	0.000	.
	Somewhat	−0.470	0.245	0.055	0.625	0.387	1.010
	Disagree	−0.090	0.146	0.539	0.914	0.687	1.217
Death preparation education (yes)		2.123	0.212	0.000	8.359	5.517	12.663
Awareness of well-dying		0.109	0.032	0.001	1.115	1.046	1.188
Suicide intention (yes)		0.676	0.400	0.091	1.965	0.897	4.306
DM (yes)		−0.660	0.193	0.001	0.517	0.354	0.755
Fracture (yes)		1.235	0.433	0.004	3.438	1.472	8.027
Insomnia (yes)		0.622	0.411	0.130	1.862	0.832	4.169
Cataract (Yes)		0.484	0.265	0.068	1.623	0.965	2.730
Fall experience over 1 year (yes)		0.006	0.296	0.983	1.006	0.563	1.799
Hearing discomfort	Comfortable	17.711	4004.037	0.996	49177412.172	0.000	
	A little uncomfortable	17.756	4004.037	0.996	51448667.699	0.000	
Vision discomfort	Comfortable	0.399	0.787	0.612	1.490	0.319	6.963
	A little uncomfortable	0.653	0.782	0.404	1.921	0.415	8.898
Chewing discomfort	Comfortable	2.073	1.036	0.045	7.948	1.044	60.532
	A little uncomfortable	1.865	1.031	0.070	6.456	0.856	48.687
	Nagelkerke $R^2 = 0.128$						

SE, standard error; OR, odds ration; CI, confidence interval; No, number; fx, frequency; DM, diabetes mellitus.

in ADs group compared to the non-ADs group. These results are consistent with the results of a previous study that participants with poorer health status are more willing to complete ADs (19). The finding that older adults with higher levels of depression, insomnia, and suicide intention are more likely to sign ADs indicates the need to focus on the mental health of older adults. Self-determining ADs

should facilitate a dignified dying; therefore, it should be done in a healthy mental and cognitive state that could fully contemplate one's dying with dignity.

Moreover, the spouse's and the participant's health status were significant influencing factors. In this study, the OR of ADs completion was lower in the normal group compared to the group in which the spouses' health status was reported as poor. In a previous study, severe spousal illness and illness severity were strongly correlated with ADs completion (42). Other chronic diseases did not significantly impact the signing of ADs; DM was a lowering factor, and fracture experience was a significant factor in signing ADs. These results may be because older adults have more opportunities to consult about ADs in a healthcare facility while hospitalized for fractures (43). Furthermore, fractures affect hundreds of thousands of older adults yearly (44). Severe complications may occur after surgeries, a hospitalization period is long, and a substantial proportion of patients will die within months of the injury (40, 41). Therefore, it is vital for patients older than 65 years undergoing these fractures to have a system that facilitates ADs completion (45).

5.1 Limitations

This study has several limitations. First, the secondary data analysis used only the variables included in the raw data. Although efforts were made to approach them as comprehensively as possible, it was challenging to identify factors that were not included in the raw data. Therefore, there are potential variables in the experimental research, including the study, that should be conducted in the future. In particular, discussions on good death, end of life, autonomy, and AD writing should be based on a variety of social and cultural backgrounds, but this paper did not explore these cultural backgrounds in depth. Therefore, we recommend future research to explore the cultural characteristics of AD writing among Koreans. Second, this study included only those community-dwelling older adults who could self-report. Thus, study findings are not generalized to older adults who are institutionalized or admitted. Future studies should include older adults admitted to a facility. Third, owing to cross-sectional secondary data, causality could not be explored; this should be clarified in a future longitudinal study.

6 Conclusion

The ADs documentation rate remains low among those aged 65 years and above. The comparison of an ADs group with a non-ADs groups in this study revealed that various general, physical, and psychological characteristics influenced the advance directives completion. Although ADs aim to reduce unnecessary medical treatment and facilitate a dignified death, the rate of ADs completion remains rather low among the older adults with high awareness of dying-well. Therefore, information dissemination regarding ADs should be promoted and relevant authorities should consider multiple options to improve the physical and psychological health of older adults, as well as their attitude toward death to increase the ADs completion rate. Furthermore, it is essential to devise creative and cost-effective person-to-person intervention strategies considering the importance of participants' ability to ask questions and receive assistance with completing ADs.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Institutional Review Board of Gachon University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SC: Conceptualization, Methodology, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. HK: Conceptualization, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

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The impact of income level on skeletal muscle health in rural Chinese older residents: a study of mediating effects based on dietary knowledge

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China's rural residents have basically solved the problem of subsistence, but due to aging, the prevalence of sarcopenia (abbreviated as sarcopenia) has been increasing year by year, especially the skeletal muscle health of the rural older residents has not been sufficiently paid attention to, so analyses of the impact of income level on the skeletal muscle health of the older people in rural areas of China are of great practical significance. Based on the annual data of the China Health and Nutrition Survey (CHNS) in 2006, 2009, and 2011, we introduced the mediator variable of dietary knowledge and used the Probit model regression, mediation effect model, and instrumental variable regression to assess the skeletal muscle health status of the rural older people in China and explore the mechanism of the influence of the income level on the skeletal muscle health of the rural older residents in China. The primary objectives of this study were to evaluate the impact of income level on the skeletal muscle health status of older adults living in rural areas of China and to investigate the underlying mechanisms. By analyzing the findings of this study, our aim is to establish a correlation between the economic status and skeletal muscle health of older adults in rural communities, as well as elucidate the influence of income level and dietary knowledge on their skeletal muscle health. Through the attainment of these objectives, we hope to provide valuable insights and recommendations for enhancing skeletal muscle health among the rural older population in China. Based on our research findings, it can be inferred that there was a significant association between the financial status of rural older adults and their skeletal muscle health. Additionally, the prevalence of sarcopenia was lower among individuals with higher income levels, and there was a negative correlation between the prevalence of sarcopenia and the level of dietary knowledge among rural older individuals. The knowledge of dietary knowledge level of rural older people plays a mediating role in the income level and the prevalence of sarcopenia. Moreover, with the change in income level and the increase in age, the change in skeletal muscle health status showed obvious heterogeneity, in which the effect on the relatively younger (65–70 years old) samples was greater. Therefore, sustained income growth remains an effective way to improve the skeletal muscle health of older rural residents. At the same time, improving dietary knowledge and dietary quality among the older people is important in preventing a decline in muscle strength and physical function and in preventing the onset of sarcopenia.

KEYWORDS

income level, rural older residents, skeletal muscle health, sarcopenia, dietary knowledge

1 Introduction

The concept of Sarcopenia was first coined by Irwin Rosenberg, a professor at Tufts University in the United States of America, to mean muscle loss (1). The most common causes of sarcopenia are aging, reduced activity, disease, and malnutrition. Sarcopenia can be divided into two main categories: primary and secondary, primary sarcopenia is mainly associated with aging (2). If other comorbidities are present along with aging, the condition is known as secondary sarcopenia. The condition known as secondary sarcopenia is more common than primary sarcopenia and requires special attention (3). According to the latest World Population Ageing Report of the United Nations Economic and Social Office, population aging has become a global trend. The Manpower Planning Office (MPO) predicts that China's population over 65 years old will grow from 10.7% in 2010 to more than 25% in 2025, and even to 41.6% in 2065 (4). According to the latest data from the National Bureau of Statistics (NBS), China's aged 65 and above is as high as 158.31 million, accounting for 11.4% of the total population. When the older population aged 65 and above accounts for 7% of the total population in a country or region, it means that the country or region is in an aging society (5). Therefore, China has entered an aging society. With the increase of the aging population, the physiological condition of the older people will deteriorate, their physical mobility will decrease, and the society of chronic diseases will increase, further accelerating the attenuation of skeletal muscle, and leading to sarcopenia. Therefore, the prevention of sarcopenia has become even more essential, and the older population is the main focus of scholars' research on the problem. As a result, preventing sarcopenia has become increasingly crucial, with scholars primarily focusing their research on the older population. Our objective is to offer valuable insights and recommendations aimed at improving skeletal muscle health among rural older adults in China. By doing so, we aspire to contribute to the overall well-being and quality of life of this demographic.

The implementation of the rural revitalization strategy was a major strategic decision made by the 19th Party and is the general gripping force of the work of "three rural areas" in the new era of socialism with Chinese characteristics. Currently, we are in the hard and decisive period of poverty alleviation, the start of the implementation of the rural revitalization strategy, and the intersection of poverty alleviation and rural revitalization (6). There are also many international studies on the relationship between income and sarcopenia. For example, Daskalopoulou Christina et al. suggested in their study that there may be a significant association between gender, marital status, education, personal economic status, and the chance of developing sarcopenia (7). Ahmadreza Dorosty suggested that there is a highly significant correlation between socioeconomic status and sarcopenia ($p < 0.001$) and that people with low socio-economic status people have 0.97 times the risk of developing sarcopenia than those in the middle and high-income brackets (8). Cassie Jeng stated that Asians have the highest prevalence of sarcopenia and black people have the lowest groups. Income level and education level both affect the prevalence of sarcopenia to a great extent in both males and females (9). Scientific studies have also shown that people of lower economic levels are more likely to overspend on healthcare and experience greater financial stress than the relatively affluent. The prevalence of sarcopenia further increases the risk of catastrophic health expenditure in the lowest socio-economic groups (10). The available evidence suggests that income is an important determinant of sarcopenia risk in older adults, but further detailed studies are needed on socioeconomic-specific pathways through which income influences sarcopenia and to make recommendations to improve skeletal muscle health in older adults.

With the rapid development of China's social and economic development, the dietary structure and eating habits of Chinese residents have also produced great changes, dietary characteristics gradually tend to be high calorie, high fat, and high sugar patterns, the risk of chronic diseases has also increased dramatically (11). In their study, Zhang Yan and Jin Shaosheng showed that consumers' personal characteristics, economic factors, cognitive and attitudinal variables, and time effects had a significant impact on the decision-making process of dairy product "consumption participation," which was mainly manifested in the fact that the higher the level of income, the higher the level of education, and the smaller the BMI value of the urban residents, the higher the degree of understanding of the Dietary Guidelines and the level of their own knowledge of the diet in general (12). According to Kang Houang, there are significant differences in dietary and nutritional knowledge, attitudes, and behaviors between low-income and high-income groups. There are two main reasons for this: firstly, high-income people can generally get better protection for their material life, and they are more capable, and they have some energy to search for channels so as to improve their dietary knowledge; on the other hand, low-income people have a relatively low level of dietary knowledge due to their economic constraints and limited energy (13). Existing evidence suggests that lower socioeconomic status is associated with an increased risk of sarcopenia (14, 15), and factors such as income, education (16, 17), and occupation (18) can have a significant impact on skeletal muscle health in older adults. Li Cheng extracted and analyzed the dietary patterns of older people from three regions by exploratory factor analysis and explored the relationship between different dietary patterns and muscle wasting disease in older people, and further analyzed the relationship between dietary nutrients and macronutrient energy supply ratios and muscle wasting disease in the older people from the perspective of dietary patterns, and explored the possible ways in which dietary patterns affect muscle wasting disease in the older residents and the related mechanisms (19). Researchers abroad have also pointed out that diet is an important exogenous factor in disease, that the development of sarcopenia is closely related to diet, and that healthier dietary patterns can help reduce the risk of sarcopenia (20).

In a study evaluating the impact of a nutrition intervention on promoting healthy eating knowledge and eating practices among

adolescents, the researchers suggested that the proposed intervention increased adolescents' dietary knowledge while improving some of their eating practices. The authors concluded that the use of a problem-posing approach and the use of food illustrations for educational activities were effective in promoting healthy eating practices among adolescents (21). Huan Wang et al. noted that nutrition and dietary education are effective in improving the dietary and nutritional knowledge and practices of people with diabetes and that such best practices help them to effectively control their blood glucose (22). Following this, in a study on the reliability of a dietary questionnaire designed to assess the eating habits, eating behavior, and nutritional knowledge of adolescents, the researchers designed the questionnaire in such a way as to identify nutritional knowledge, knowledge of food safety, etc., as the main factors influencing the eating habits of adolescents and as a basis for the possibilities of improving eating habits (23). Simultaneously, a recent national study of 697 Chinese adolescents (aged 12–17 years) showed that dietary and nutritional knowledge and social attitudes were among the main predictors of food preferences (24). Jane Kolodinsk, in a study of college students' knowledge of current dietary guidelines and college students' food choices, concluded that dietary knowledge was associated with making healthier food choices and that increased dietary knowledge was positively correlated with healthier eating patterns. Overall, those with better dietary practices had higher levels of dietary knowledge. The authors suggest that dietary guidelines should be combined with effective public awareness campaigns and thus become an effective mechanism to promote changes in household dietary choices (25).

However, there are no studies that directly show whether people's level of dietary knowledge can directly affect skeletal muscle health, so how dietary knowledge specifically affects skeletal muscle health still requires further research.

As of now, there are a number of methods available to assess skeletal muscle mass, skeletal muscle strength, and skeletal muscle function, researched fat-free body weight, calf circumference, upper arm circumference, skin fold thickness measurements, grip strength, knee flexion/extension, relative skeletal muscle index, electromyography, gait analysis, lower extremity strength, CT, magnetic resonance imaging (MRI), and ultrasound (26), CT, magnetic resonance imaging (MRI), and ultrasound testing (26). However, there has been a lack of recognized diagnostic criteria for sarcopenia, and Baumgartner RN et al. published a diagnostic method for sarcopenia in 1998, which uses height-related muscle mass to diagnose the degree of sarcopenia (27). Appendicular skeletal muscle mass (ASM) is measured using the DXA, and the ratio of the square of the skeletal muscle mass of the limbs (kg) to the height (m) is the skeletal muscle index (SMI); if the SMI is less than 2 standard deviations below that of a healthy young person of the same sex, then the person is likely to have sarcopenia. Then there is a high probability of having sarcopenia (28). Bioelectrical impedance analysis (BIA) can also be used, which does not measure muscle mass directly but gives an estimate of muscle mass based on whole-body conductivity and is affordable, widely available, and portable (29). In addition to this, measures of physical function such as the balance test, 4 m timed walk test and timed sit-to-stand test can add to the diagnostic strength of sarcopenia, and these tests can predict the risk of disability and help in the determination of preclinical sarcopenia.

This study aims to investigate the mechanisms by which income level affects skeletal muscle health among rural older residents in China, and to introduce dietary knowledge as a mediating variable. By defining a clear research objective, we can gain insight into the influencing factors of skeletal muscle health among rural older residents, especially the relationship between income level and dietary knowledge. Therefore, this study focuses on the following questions: do higher income levels and increased dietary knowledge reduce the prevalence of sarcopenia? By what mechanism do they exert this effect? Compared with the existing literature, the possible academic contributions of this study include: In addition to quantitatively analyzing the effects of income level and dietary knowledge on the population of sarcopenia patients and their food nutrient intake, it is more important to clarify the mechanism of the influence of income on the incidence of sarcopenia in rural older people by constructing theoretical models and empirical tests, which is of great significance for enhancing the dietary nutritional system of the population and promoting the implementation of the strategy of Healthy China.

2 Research framework and methods

2.1 Research framework

There is a hypothesis that improving the income level of older residents in rural areas can have an impact on the skeletal muscle health status of rural older people. This is because increasing income may lead to an increase in dietary knowledge, which in turn can contribute to a lower prevalence of sarcopenia among this population. On the basis of existing literature and theory, this paper constructs a framework diagram for analyzing the mediating effect of dietary knowledge level in the relationship between income and the prevalence of sarcopenia in rural older adults (Figure 1). Three variables are involved in this study: income level, dietary knowledge, and prevalence of sarcopenia among rural older adults.

Older adults with higher incomes may have easier access to more and better foods, including foods high in protein, vitamins, and minerals. This may contribute to maintaining muscle mass and reducing the risk of sarcopenia. Since it has been documented that higher-income people are in better health and use more healthcare services (30), research hypothesis 1 is proposed:

> *H1*: The higher the income level of rural older adults, the lower the prevalence of sarcopenia.

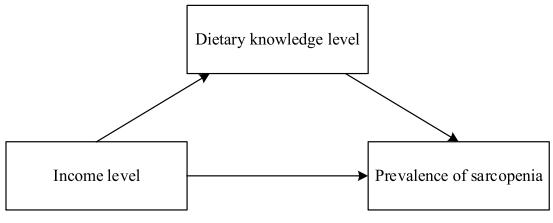

FIGURE 1
Theoretical model.

Education and health are two critical forms of human capital, and it is widely established in economics that education can produce health gains. It has been shown that the most important factor influencing the improvement of dietary quality of US residents is the increase in the level of education rather than the level of income (31) and that an increase in the level of education can lead to healthier dietary behaviors, which in turn promotes better health (32). Therefore, research hypothesis 2 is proposed:

> *H2*: The higher the income level of rural older adults, the higher the level of dietary knowledge.

Further, as individuals possess a higher level of dietary knowledge, they are more likely to make food choices that promote muscle retention and growth, thereby reducing the risk of sarcopenia. Based on this understanding, we propose research hypothesis 3:

> *H3*: There exists a negative correlation between the level of dietary knowledge and the prevalence of sarcopenia among rural older individuals.

Taking into consideration that relatively younger older adults are typically still within the working age range and are more vulnerable to socio-economic factors (33) such as occupation, level of education, and socio-economic status.

If the income level is comparatively low, it may affect their nutritional intake, health status, and access to healthcare behaviors. Therefore, research hypothesis 4 is proposed:

> *H4*: The relationship between income level and prevalence of sarcopenia varies across age groups.

2.2 Model setting

In this study, we constructed a mediation effect model of "income—dietary knowledge—prevalence of sarcopenia among rural older person," and analyzed the impact of income level on sarcopenia among rural older residents, using dietary knowledge of rural older residents over 65 years old as the mediator variable. The mediating effect model of "dietary knowledge-prevalence of sarcopenia" was used to analyze the effect of income level on sarcopenia among rural older people aged over 65, with dietary knowledge as the mediating variable. The basic idea is to first analyze the effect of income level on the prevalence of sarcopenia among rural older people to obtain the total effect of income on the prevalence of sarcopenia among rural older people, then analyze the direct effect of income level on dietary knowledge among rural older people, and finally analyze the effects of income level and dietary knowledge on the health of older people's skeleton muscles to obtain the mediating effect of dietary knowledge.

The baseline model is constructed as follows:

$$ASMI_i = \alpha_0 + \alpha_1 income_i +_r C + \mu_{1i} \quad (1)$$

$$DK_i = \beta_0 + \beta_1 income_i +_r C + \mu_{2i} \quad (2)$$

$$ASMI_i = \chi_0 + \chi_1 income_i + \chi_2 DK_i +_r C + \mu_{3i} \quad (3)$$

$ASMI_i$ is individual skeletal muscle health and is a continuous variable, $income_i$ is the individual income of the observer, DK_i is a mediating variable indicating the level of dietary knowledge of the observer, C is a control variable, and φ_i is an error term. α_1 in Eq. (1) denotes the total effect of income of rural older residents on skeletal muscle health index, in Eq. (2), β_1 denotes the effect of income of rural older people on the level of dietary knowledge, and in Eq. (3) χ_1 denotes the direct effect of the level of income of rural older people on the index of skeletal muscle health, and χ_2 denotes the mediating variable the level of dietary knowledge on skeletal muscle health effect.

Substituting Eq. (2) into Eq. (3) yields:

$$ASMI_i = (\chi_0 + \chi_2\beta_0) + (\chi_1 + \chi_2\beta_1) income_i +_r C + \mu \quad (4)$$

In Eq. (4) $(\chi_0 + \chi_2\beta_0)$ denotes the total effect of income on the skeletal muscle health index of the rural older residents, $\chi 1$ denotes the direct effect of income on the skeletal muscle health index of the rural older residents, and $\chi 2\beta 1$ denote the indirect effect of the level of dietary knowledge. $\chi 2\beta 1/\ \alpha 1$ is the mediating effect of dietary knowledge.

3 Data sources and variable selection

3.1 Data sources

Data for this study come from the China Health and Nutrition Survey (CHNS). This survey is jointly conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Health (NINH) of the Chinese Center for Disease Control and Prevention (CDC), with the aim of understanding how broader social and economic changes in China are affecting nutritional and health-related outcomes among Chinese residents. The CHNS is a continuous survey conducted annually among approximately 4,000 urban and rural households in nine provinces in China (i.e., Guangxi, Guizhou, Henan, Heilongjiang, Hubei, Hunan, Jiangsu, Liaoning, and Shandong; in 2011, the three cities of Beijing, Chongqing, and Shanghai were included). The CHNS is a continuous survey of approximately 4,400 households in urban and rural areas in nine provinces in China (i.e., Guangxi, Guizhou, Henan, Heilongjiang, Hubei, Hunan, Jiangsu, Liaoning, and Shandong; in 2011, the cities of Beijing, Chongqing, and Shanghai were included). The nine provinces include northern and southern regions, developed eastern coastal areas, and poor remote areas, which vary widely in terms of geography, economic development, public resources, and health indicators. The sample was selected through a multi-stage randomized clustering strategy and can therefore be taken as representative of the Chinese population.

Older people's own basal metabolism decreases, their body functions in all aspects decline, and physical activity is insufficient, which is more likely to lead to sarcopenia. At the same time, the living environment of the rural older residents is relatively closed, lack of external information and communication, it is difficult to come into contact with new dietary knowledge levels. Therefore, the focus

group in this paper is the rural older residents over 65 years old. In this study, the data from the three surveys in 2006, 2009, and 2011 were selected because the survey only began to ask the interviewed individuals for dietary knowledge information in 2004, but the differences between the question options in 2004 and the subsequent surveys led to systematic differences between the dietary knowledge in 2004 and the data from the subsequent three surveys, and the data on dietary nutrition of the population in 2015 have not yet been opened.

3.2 Variable selection

3.2.1 Explained variables

The main clinical manifestations of sarcopenia are muscle weakness, which reduces the mobility of the rural older residents, causing difficulties in completing daily movements such as walking, sitting and standing, climbing and lifting heavy objects, and even leading to balance disorders, difficulty in standing, and a high susceptibility to falls. Many methods can be used to assess skeletal muscle mass, skeletal muscle force, and skeletal muscle function. Specific assessment criteria are based on AWGS recommendations and include muscle strength, extremity skeletal muscle mass (ASM), and physical performance.

Extremity Skeletal Muscle Mass: The AWGS 2019 cut-off values for low muscle mass in the diagnosis of sarcopenia are as follows: <7.0 kg/m^2 for men and < 5.4 kg/m^2 for women by DXA, and < 7.0 kg/m^2 for men and < 5.7 kg/m^2 for women by BIA. Skeletal muscle mass in the Chinese population was physically measured using the Wen et al. formula to estimate it (34). The calculation formula is as follows:

$$\begin{aligned}\mathrm{ASM} = {} & 0.193 \times \mathrm{weight}\,(\mathrm{kg}) + 0.107 \times \mathrm{height}\,(\mathrm{cm}) \\ & - 4.157 \times \mathrm{gender} - 0.037 \times \mathrm{age}\,(\mathrm{years}) - 2.631\end{aligned}$$

Gender is set to 1 if male and 0 otherwise. Several studies have shown that ASM calculated using this formula agrees well with dual-energy X-ray absorptiometry (DXA). In 2014, the Asian Working Group on Sarcopenia (AWGS) developed cut-offs for the measurement of sarcopenia in Asian populations: Muscle mass is measured as ASMI, and the cut-offs for males and females when applying bio refractor measurement (BIA) are the cut-off values for males and females were 7.0 kg/m^2 and 5.7 kg/m^2, respectively, when measured by bioelectrical impedance measurement (BIA).

3.2.2 Explanatory variables

3.2.2.1 Measurement of dietary knowledge

In order to measure dietary knowledge, three composite indicators were established to measure the level of residents' dietary knowledge based on the questions in the dietary knowledge table of the CHNS questionnaire. The dietary knowledge section of the CHNS questionnaire includes 9 questions (Table 1). The answers to these questions are not always correct, therefore, the judgment of each question is given by this paper with reference to the criteria of Zhang Zongli et al. (35) as follows, as shown in the table.

For each question in the dietary knowledge questionnaire, respondents were asked to give their answers from five options: strongly disagree, disagree, neutral, agree, and strongly agree. In this paper, we refer to Zhang Zongli et al.'s method of treatment and assign the five indicators of strongly disagree, disagree, neutral, agree, and strongly agree to scores of 1, 2, 3, 4, and 5, with higher scores indicating higher levels of dietary knowledge. Not all of the answers to the nine questions were correct, and higher scores for questions 2, 4, and 6 in the questionnaire indicated lower levels of dietary knowledge. Therefore, the scores for these three questions were re-directed so that higher scores indicated higher levels of dietary knowledge for all questions. The selection of indicators was based on Zhou et al.'s study, in which the samples' answers to the dietary knowledge questions were judged as "correct" and "incorrect," with one point for a correct answer to the question and zero points for the other answers (36). The scores of the nine questions for each sample were summed up as a composite indicator of their dietary knowledge endowment.

TABLE 1 Question design and statistic index of dietary knowledge.

Question	Presentation of the problem	Judgment
1	Eating a diet with plenty of fruits and vegetables is good for health.	T
2	Eating more sugar is good for health.	F
3	Eating different kinds of food is good for health.	T
4	Eating foods high in fat is good for health.	F
5	Eating a diet with lots of staples is not good for health.	T
6	Eating a lot of meat every day is good for health	F
7	Eating less meat and animal fat at meals is good for health.	T
8	Drinking milk and eating dairy products are good for health.	T
9	Beans and soy products are good for health.	T

3.2.2.2 Income level

Total household income is calculated from nine sources of income including business, farming, fishing, and gardening. *Per capita* household income is obtained by dividing total household income by household size. A logarithmic term for income was added based on the possible non-linear relationship between income and skeletal muscle health.

3.2.3 Control variables

Much of the current literature suggests that personal and family characteristics can have an impact on the level of skeletal muscle health in older adults. In order to make the results of the analysis more accurate, personal and family characteristics and other variables were selected as control variables in this paper. Individual characteristic variables include height, weight, age, education level, and family size.

3.3 Descriptive statistical analysis

Descriptive statistical analysis is provided in Table 2.

3.4 Correlation and covariance test

Before the regression, the test of Pearson correlation coefficient matrix was carried out first, and the test results are shown in Table 3, which indicated that the core explanatory variable of *per capita* household income and the prevalence of sarcopenia had a significant negative correlation, which was consistent with the expected hypotheses, and that the control variables, such as age and level of education, had a significant correlation with the dependent variable at least at the significance level of 1%, but the results are for reference only, taking into account the fact that the correlation coefficient matrix only measured the relationship between the two variables. However, considering that the correlation coefficient matrix only measures the relationship between the two variables and does not exclude the interference of control variables and potential variables, the results are for reference only, and the specific relationship needs to be determined by further regression analysis. In addition, by determining whether the absolute value of the correlation coefficient between the explanatory variables is greater than 0.9, we can also preliminarily rule out the possibility of covariate covariance.

The dietary knowledge questionnaire in the CHNS data is set up with multiple questions to measure the level of dietary knowledge of individuals by asking their views. While multiple indicators can provide rich information for the study from different perspectives and reflect the level of dietary knowledge of the residents in a more comprehensive way, they also increase the complexity and difficulty of the analysis, and there may be a certain degree of correlation between different indicators, and the multiple covariances will lead to large errors in the estimation results. In order to avoid covariance in the data, a multicollinearity test is needed, which is generally used to detect whether there is multicollinearity through the variance inflation factor VIF: it is the ratio of the variance when there is multicollinearity between the explanatory variables to the variance when there is no multicollinearity. The larger the inverse of the tolerance VIF, the more serious the covariance. The empirical judgment method shows that: when $0 < VIF < 10$, there is no multicollinearity; when $10 \leq VIF < 100$, there is strong multicollinearity; when $VIF \geq 100$, there is severe multicollinearity. Table 4 shows the results of the multicollinearity test of the model, and it can be seen that the VIF value of each variable is less than 10, thus overall, the indicators selected in this paper do not have covariance.

4 Results

4.1 Baseline regression analysis of the effect of income on the prevalence of sarcopenia among rural older people

In this study, we first conducted a baseline regression of income and prevalence of sarcopenia among rural older people using the Probit model to clarify the relationship between income and prevalence of sarcopenia among rural older residents. Table 5 reports the regression results of income on the prevalence of sarcopenia among rural older residents. The regression results in columns (1), and (2) show that income is significant at the 1% level where the regression coefficient of the logarithm of *per capita* household income is negative indicating that the prevalence of sarcopenia decreases as the income level increases. Based on this result, hypothesis 1 of this study was tested.

Income level has a significant negative impact on the prevalence of sarcopenia among rural older residents, and there is a potential

TABLE 2 Definition of main variables and descriptive statistical analysis.

Variable name	Statistical analysis	Obs	Mean	SD	Min	Median	Max
Skeletal muscle mass	Calculated	1,496	0.172	0.377	0.000	0.000	1.000
Log *per capita* household income	Calculated	1,496	9.155	0.908	4.804	9.230	13.017
Age	Actual age in the year of interview	1,496	70.756	4.974	65.000	69.000	91.000
Education level	0 = None; 1 = Primary school graduate; 2 = Junior high school graduate; 3 = High school graduate; 4 = College; 5 = Bachelor's degree	1,496	1.106	1.330	0.000	1.000	5.000
Family size	Based on the CHNS database	1,496	3.229	1.872	1.000	2.000	13.000
Working time	Based on the CHNS database	1,496	2.586	3.117	0.000	1.000	18.000
Dietary knowledge	Calculated	1,496	6.316	2.068	0.000	7.000	9.000

TABLE 3 Correlation coefficient matrix.

Variable	Prevalence of sarcopenia	Log *per capita* household income	Age	Education level	Family size	Working time	Dietary knowledge
Prevalence of sarcopenia	1.000						
Log *per capita* household income	−0.110***	1.000					
Age	0.135***	0.082***	1.000				
Education level	−0.040	0.278***	−0.053**	1.000			
Family size	0.093***	−0.267***	−0.084***	−0.062**	1.000		
Working time	0.102***	−0.233***	−0.258***	−0.272***	0.065**	1.000	
Dietary knowledge	−0.082***	0.202***	−0.011	0.254***	−0.045*	−0.174***	1.000

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

TABLE 4 Covariance test.

Variable	VIF	1/VIF
Working time	1.201	0.833
Log *per capita* household income	1.196	0.836
Education level	1.163	0.860
Age	1.098	0.910
Family size	1.081	0.925
Mean VIF	1.148	0.873

endogeneity issue when exploring the relationship between income level and skeletal muscle health among rural older people in terms of *per capita* household income. Specifically, on the one hand, personal income affects BMI, which in turn affects skeletal muscle health; at the same time, BMI also affects *per capita* household income by influencing skeletal muscle health, so it can be inferred that skeletal muscle health also affects the level of *per capita* household income; on the other hand, some omitted variables are related to both *per capita* household income and skeletal muscle health. Potential endogeneity problems can lead to biased estimates of the coefficients of the independent variables.

The instrumental Variable Method is widely used to solve the endogeneity problem, "Instrumental Variable Probit" (IV Probit) and(the two-step Method) are academically recognized as two effective methods for testing the endogeneity of the Probit model (37), the bi-directional relationship between skeletal muscle health and income in this study can lead to endogeneity problems in the model, the potential endogeneity between income and the prevalence of sarcopenia may affect the stability of the conclusions, and the Probit model was used in this study, so the use of the instrumental variable Probit method can effectively address the endogeneity of income. Taking into account the availability of data, this study will refer to Tian and Yu's selection of the instrumental variable for income in the CHNS (38), and use the variable "how many televisions the household has that can be watched" as the instrumental variable for income, and use the instrumental variable estimation method of 2SLS for the comparative analyses. The reason is that wealth status is a potentially valid instrumental variable for household income level, and "how many TVs the household can watch" can effectively represent household wealth.

Table 6 reports the regression results, the first stage regression results show that "the number of TV sets available for viewing in the household" has a significant positive effect on "household income *per capita*," i.e., "the number of TV sets available for viewing in the household" has a good explanatory power on the level of household income *per capita*. In other words, "the number of TV sets that can be watched at home" has good explanatory power for the level of *per capita* household income, and the variable "the number of TV sets that can be watched at home" can be used as an instrumental variable to satisfy the test of relevance, which can help to accurately identify the impact of income level on skeletal muscle health. Further endogeneity test, the Wald test indicates that *per capita* household income is an endogenous variable, which should be corrected by the instrumental variable method. In order to better address the endogeneity of the model, a weak instrumental variable test was conducted, the test results significantly rejected the original hypothesis, indicating that "how many TV sets can be watched in the household" is not a weak instrumental variable. Considering that the number of instrumental variables is equal to the number of endogenous variables, the instrumental variables are identified exactly.

4.2 Analysis of the mechanism of action of the effect of income on the prevalence of sarcopenia in rural older people

4.2.1 Mediating effects of income on the prevalence of sarcopenia in rural older people through dietary knowledge levels

In this study, the mediation effect test of nutritional intake was conducted using the mediation effect model, and the validation of the mediation effect of the variable level of dietary knowledge was carried out using the stepwise method, and the results are shown in Table 7. The first step was to verify the relationship between the independent and dependent variables, i.e., the effect test of *per capita* household income and the prevalence of sarcopenia, which was partially demonstrated in the baseline regression in the previous section, i.e., *per capita* household income was negatively correlated with the prevalence of sarcopenia at the 1% level of significance. In the second step, the dependent variable was replaced with the mediator variable to investigate whether there was a significant correlation between the independent variable and the mediator variable, and the results showed that *per capita* household income was positively correlated with dietary knowledge at the 1% significance level, and the significant relationship was established. The third step is to add the mediator variable on the basis of the first step and conduct regression again, if the mediator variable is significant, it indicates that there is a mediation effect, and the results show that the level of dietary knowledge is positively correlated with the prevalence of sarcopenia at the 1% significance level, so the mediation effect exists, and the level of dietary knowledge of the older person in rural areas mediates the role of knowledge of the level of income and the prevalence of sarcopenia.

4.2.2 Heterogeneity analysis of the effect of income on the prevalence of sarcopenia among rural older people through their level of dietary knowledge

Table 8 provides heterogeneity analysis.

4.2.3 Robustness test of the effect of income on the prevalence of sarcopenia in rural older people through dietary knowledge levels

In order to test the robustness of the findings, we used Logit and LPM methods to estimate the intervention effect again. Firstly, the regression analysis was carried out using the Logit model, which eliminated the effect of extreme data and allowed us to study the factors influencing the prevalence of sarcopenia in rural older residents more accurately. Then the LPM model was used to test the results again, and it can be seen that under both models, the prevalence of sarcopenia in rural older people is negatively correlated with *per capita* household income the results are significant, and the results of the study are basically the same as the previous article. Therefore, by combining the above robustness results, the findings of this study have a certain degree of reliability (see Table 9).

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TABLE 5 Baseline regression results.

Variable name	(1)	(2)
	Prevalence of sarcopenia	Prevalence of sarcopenia
Log *per capita* household income	−0.178*** (−4.32)	−0.141*** (−3.11)
Age		0.055*** (6.75)
Education level		0.036 (1.14)
Family size		0.065*** (3.05)
Working time		0.066*** (5.07)
Constant	0.669* (1.78)	−4.016*** (−5.52)
Observations	1,496	1,496
R^2	0.0130	0.0586

*, **, **** indicate significant at the 10, 5, and 1% levels, respectively; standard deviations are in parentheses. Prevalence of sarcopenia (1) is without control variables; (2) is with control variables.

TABLE 6 Instrumental variable regression of *per capita* income of older rural residents.

Variable name	Stage 1	Stage 2
	Per capita household income	Revised *per capita* household income
How many TVs are available for viewing in the household	0.303*** (10.60)	
Log *per capita* household income		−0.751*** (−3.61)
Age	0.008* (1.70)	0.059*** (6.79)
Education level	0.132*** (7.98)	0.132*** (2.82)
Family size	−0.157*** (−12.72)	−0.008 (−0.25)
Working time	−0.032*** (−4.12)	0.040** (2.41)
Constant	8.708*** (26.08)	1.462 (0.74)
Observations	1,496	1,496
Wald test (P > chi^2)	0.0015	

Probit regression coefficients are shown in the tables and standard errors are in parentheses. The coefficients on per capita household income in the tables are those estimated using instrumental variables. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

TABLE 7 Intermediation effect.

Variable name	(1)	(2)
	Dietary knowledge	Prevalence of sarcopenia
Log *per capita* household income	0.296*** (4.69)	−0.131*** (−2.88)
Dietary knowledge		−0.034* (−1.82)
Age	−0.016 (−1.35)	0.054*** (6.70)
Education level	0.292*** (8.13)	0.047 (1.43)
Family size	0.005 (0.17)	0.065*** (3.06)
Working time	−0.068*** (−3.88)	0.063*** (4.88)
Constant	4.547*** (4.46)	−3.847*** (−5.30)
Observations	1,496	1,496
R^2	0.092	–
Adj.R^2	–	0.0608

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

TABLE 8 Heterogeneity analysis.

Variable name	Age 65–70	Age over 70
	Prevalence of sarcopenia	Prevalence of sarcopenia
Log *per capita* household income	−0.157** (−2.52)	−0.119* (−1.80)
Age	0.069* (1.73)	0.062*** (4.49)
Education level	0.024 (0.48)	0.052 (1.21)
Family size	0.064** (2.17)	0.057* (1.86)
Working time	0.039** (2.34)	0.100*** (4.85)
Constant	−4.694* (−1.67)	−4.841*** (−3.95)
Observations	757	739
R^2	0.0355	0.0681

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

5 Conclusions and implications

5.1 Conclusion

This study examined the mediation effect of income and dietary knowledge on the prevalence of sarcopenia among older rural residents using data from the China Health and Nutrition Survey (CHNS) in 2006, 2009, and 2011. The main conclusions are as follows:

(1) The higher the income level of rural older adults, the lower the prevalence of sarcopenia. This finding is consistent with the conclusion proposed by Zhang et al. that advanced-age individuals with cognitive decline, low income, smoking, malnutrition, and decreased exercise time are risk factors associated with age-related skeletal muscle atrophy (39).

(2) In this study, the level of dietary knowledge was used as a mediating variable to reveal the mechanism of action by which income level affects skeletal muscle health in rural older adults. The empirical results showed that the higher the income level of rural older residents, the higher the level of dietary knowledge. Meanwhile, dietary knowledge was negatively correlated with the prevalence of sarcopenia among rural older residents. Therefore, for older residents with sarcopenia, improving their dietary knowledge can effectively reduce their calorie intake and achieve the dual effects of controlling body weight and maintaining and increasing muscle mass.

(3) Dietary knowledge level played an intermediary role in income level and the prevalence rate of sarcopenia in rural older residents. This suggests that increased dietary knowledge can have an impact on income levels and the prevalence of sarcopenia. Increased knowledge of dietary nutrition and effective nutritional guidance can help older rural residents improve their dietary habits and increase their nutritional intake to improve their quality of life and skeletal muscle health.

TABLE 9 Robustness test.

Variable name	Logit	LPM
	Prevalence of sarcopenia	Prevalence of sarcopenia
Log *per capita* household income	−0.034*** (−2.87)	−0.240*** (−3.03)
Age	0.014*** (6.36)	0.097*** (6.72)
Education level	0.010 (1.30)	0.066 (1.15)
Family size	0.016*** (2.78)	0.111*** (2.96)
Working time	0.016*** (4.82)	0.116*** (5.15)
Constant	−0.618*** (−3.17)	−7.103*** (−5.49)
Observations	1,496	1,496
R^2	0.054	0.0578

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

(4) The relationship between income level and the prevalence of sarcopenia among rural older adults varies by age. There is heterogeneity in the effect of income growth on the prevalence of sarcopenia among older rural residents, and this effect is more pronounced for the relatively younger older age groups.

The main contribution of this study is that it focuses on the mechanism of the influence of income on the prevalence of sarcopenia in rural older adults from the perspective of dietary knowledge level, which makes up for the current lack of research on the intrinsic mechanism of the influence of income on skeletal muscle health indices in rural older residents. However, due to data limitations, this paper fails to analyze the impact of dietary knowledge acquisition on the skeletal muscle health of rural older residents. This study will provide a reference for the governmental authorities to formulate policies to improve the dietary knowledge of the population.

5.2 Enlightenment

WHO proposes that health assessment indicators for the older residents focus on the ability to live independently, i.e., whether they are able to live on their own, rather than just death and illness (40). The main purpose of this paper is to investigate the influencing factors of sarcopenia among rural older people based on their income level and dietary knowledge and to take timely and effective interventions to minimize the incidence of sarcopenia and prevent the reduction of muscle strength from affecting the ability of older people to take care of themselves, so as to improve the quality of life of the older people and to prolong their lifespan.

Based on the conclusions of the above studies, the following policy recommendations are put forward to reduce the prevalence of sarcopenia in China, accelerate the construction of a healthy China with the people as the center, and implement the strategy of a healthy China: Firstly, increasing the income of farmers is still an important means to improve the dietary health level of the rural residents and to reduce the prevalence of sarcopenia in rural residents. Vigorously supporting the lower income groups in rural areas to achieve sustainable growth of low income, but also to respond to the national policy requirements of "precise poverty alleviation," and at the same time to improve the level of dietary knowledge of rural residents to improve their skeletal muscle health. Secondly, government departments, nutrition, and health organizations, educational institutions, and other organizations and institutions should formulate more concise dietary guidelines, widely disseminate dietary knowledge, actively promote a rational diet, and focus on giving dietary guidance to people suffering from sarcopenia. Through regular nutritional knowledge lectures and the distribution of healthy diet brochures, the dietary knowledge of the Chinese population can be increased, and unhealthy dietary behaviors can be adjusted. Thirdly, it is paying attention to the dietary and nutritional situation of low-income groups of rural older people, promoting balanced nutrition through the distribution of food vouchers, and the strengthening of nutritional dietary publicity, so as to reduce the incidence of sarcopenia and improve the health of the population.

Data availability statement

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

Ethics statement

Ethical approval was not required for the studies involving humans because the data obtained by this study is not private and is anonymous and therefore does not require ethical approval. 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

XZ: Formal analysis, Writing – original draft. GW: Conceptualization, Writing – review & editing. JM: Visualization, Writing – review & editing. HB: Supervision, Writing – review & editing.

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Conflict of interest

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

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Exploring non-linear effects of walking accessibility on well-being in rural older adults of Jintang County: a random forest analysis

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Objective: The global concern surrounding the aging population has brought the well-being of older individuals to the forefront of societal attention. Unfortunately, studies focusing on the well-being of older people residing in rural areas are frequently overshadowed by the developmental disparities between rural and urban regions. Thus, this study aims to delve into the non-linear impact of walking accessibility on the subjective well-being of rural older adults. The goal is to gain a comprehensive understanding of this relationship, ultimately contributing to an improved quality of life and health for older adults in rural areas.

Methods: In this study, the Random Forest algorithm was employed to explore the non-linear effects of demographic variables, perceived safety, subjective built environment (including perceptions and preferences of the built environment), and walking accessibility on the subjective well-being of older adults.

Results: The findings of this study underscore the pivotal role of walking accessibility in influencing the well-being of older adults, particularly in terms of access to bazaars and health centers, where non-linear and threshold effects are evident. Furthermore, community safety, road conditions, and walking preferences were identified as positive influencers on the well-being of older adults. Well-being trends varied with age, revealing noteworthy non-linear relationships for certain variables.

Conclusion: The insights gained from this study provide crucial theoretical guidance for the development of policies tailored to the unique context of rural aging. By taking into account factors such as walking accessibility, community safety, health support, and social interaction, we can create an improved living environment for rural older adults, ultimately enhancing their happiness and overall quality of life.

KEYWORDS

accessibility, well-being, random forest model, rural older adult, non-linear

1 Introduction

Contemporary social development and medical progress have led to lower fertility rates and increased life expectancy, contributing to the increasing prevalence of an aging population worldwide (1). The rural older adult population occupies a considerable proportion in many countries (2, 3). For example, in China, a country with the largest older adult population in the world, the rural older adult population over 65 years accounts for 18.57% of the rural population (4, 5). In the context of global aging, society is becoming more concerned about the well-being of older adults (6). The gap caused by the essential difference between urban and rural older adult care makes the subjective well-being research of the rural older adult population have practical significance and deserve people's attention (7, 8). However, most studies on subjective well-being in older people do not focus on rural areas (9), and the well-being of rural older adults has received relatively little attention. Exploring the influence mechanism of the subjective well-being of the rural older adult population in China will provide a practical reference path for improving the flourishing of the global rural older adult population.

Subjective well-being refers to the cognitive evaluation of life satisfaction. As a comprehensive subjective feeling index, it can reflect older adults' experience of life satisfaction and happiness (10). Although subjective well-being is a complex concept, empirical research has made great progress over the past decade (11–15). Existing literature has demonstrated that 30 to 40% of individuals' well-being is attributable to genetic factors (13, 16). On the other hand, between 60 and 70% of subjective well-being can be attributed to environmental effects (16). Many studies have explored subjective well-being from multiple perspectives, including social environment, built environment, personal perception level, and so on (17–19). However, among these perspectives, mobility plays a significant role in maintaining the subjective well-being of older adults (17, 20–22). Low mobility may prevent older adults from engaging in social activities, leading to low mood, depression, and loneliness (23–26). A good living environment is a key factor in improving the mobility of older adults, which includes reasonable community planning, namely providing convenient walking roads and public facilities, and the creation of a safe and friendly living environment (27–30). Through these community planning measures, older people can be more willing to go out and travel by foot. In this context, walking accessibility becomes an essential factor affecting subjective well-being among older adults. Several studies have shown that walking accessibility directly affects residents' subjective well-being (17, 19, 31). However, existing studies are mainly based on linear models, ignoring the complex and diverse non-linear influence relationships that may exist (29, 32, 33). Therefore, this study aimed to explore the non-linear effects of walking accessibility on subjective well-being in rural older adults. It is expected to help rural older adults improve their subjective well-being.

Because the built environment is considered to effectively affect the daily life of residents (34–36), its impacts on subjective well-being have always been one of the more comparatively noticed topics (4, 30, 37). As a special vulnerable group, older people's physical health status and self-care ability will be more vulnerable to the built environment than other age groups (38), which might affect their subjective well-being (39). Generally, the built environment can be summarized as density, diversity, design, destination accessibility, and distance to transit (40). These elements are closely related to the vitality and attractiveness of the community, where destination accessibility directly affects the convenience of people to travel and thus affects the frequency of social interaction. If the destination's accessibility is low, it may lead to spending more time and energy on travel, thus reducing social interaction and making people feel lonely (41). In addition, destination accessibility is also closely related to physical health and quality of life (42). A review suggests that environmental factors such as accessibility and green space quality can impact citizens' physical activity (43). Destination accessibility can encourage people to walk, ride, or use public transport more often than relying on private cars, especially older people, who usually use cars less frequently (36). The present study fully considers the rural-specific environmental characteristics when exploring the subjective well-being of older people in rural areas. For example, rural areas may be more dispersed and distances between the walking target sites may be larger, which may affect walking accessibility and subjective well-being in older adults. At the same time, green and natural resources may be more abundant in rural areas, which will also affect the happiness of older adults. In addition to walking accessibility, the subjective well-being of rural older adults may be influenced by multiple other factors, for example, social support, health status, financial status, and community friendliness. Therefore, these potential confounding factors need to be controlled for or considered in studies to more accurately assess the effect of walking accessibility on subjective well-being in rural older adults. In conclusion, this study aimed to investigate the non-linear effects of walking accessibility on the subjective well-being of rural older adults and to consider the influence of rural environmental characteristics and other potential factors. Through scientific research design and rational statistical analysis, it is expected to provide helpful advice and decision support for improving the quality of life and subjective older adults' well-being in rural regions, as well as for promoting sustainable development in rural communities.

This study conducted a detailed travel survey of 515 respondents in rural Sichuan, China, applying a random forest algorithm to explore the non-linear effects of demographic variables, safety perception, subjective built environment (perception and preference), and walking accessibility on the subjective well-being of older adults. Compared with traditional linear models, random forest is better able to estimate the relative importance of different influencing factors to the dependent variable and effectively capture the non-linear relationship between features, thus providing more accurate and reliable prediction results. The study's contribution encompasses three aspects: firstly, it re-examined the influence of walking accessibility, subjective building environment, and safety perception on older adults, emphasizing the importance of these factors in affecting older adults' well-being. Secondly, this study provides a new perspective on rural construction layout planning for the well-being improvement of older adults in rural areas. Third, machine learning was used to explore the nonlinear relationships, providing empirical support and valuable reference for improving the life happiness of older people residing in rural.

2 Method and data

2.1 Study area, survey method, and data

Jintang County, affiliated with Chengdu City, Sichuan Province, is located northeast of the Chengdu Plain. By the end of 2021, the total registered population of Jintang County had reached 904,000 (44). As

an important link to the Chengdu Plain economic circle, Jintang County has been identified as the characteristic industrial development area of Chengdu City and is a typical demonstration county of urbanization development in Chengdu suburbs (45). Therefore, in this study, under the background of Jintang County, Guancang and Qingjiang towns were randomly selected from 19 towns/streets as samples, and on this basis, 11 sample villages were selected for household survey in January 2021. The following points are mainly considered when determining the sample villages: First, the rural transportation and infrastructure are well-developed. Second, Guancang Town and Qingjiang Town residents have a relatively traditional lifestyle, and the pace of life is relatively slow. Most farmers still take farming as their main occupation, and some also engage in aquaculture, which aligns with the lifestyle of Chinese rural residents.

The data used in this study are mainly in two parts. First, individual-level data includes socio-demographic information, subjective well-being measures, built environment perception and preferences, and physical activity information for older adults (see Appendix for descriptions of specific variables). In the process of the investigation, a random one-to-one questionnaire survey was conducted, ensuring that every individual in the target population had an equal chance of being selected. Researchers approached every older adult encountered in the survey area. If a respondent was unwilling to participate, the researcher would promptly move on to the next individual. This approach maximized the reduction of any potential subjectivity or selection bias from the researchers' side. Each questionnaire took an average of 9 min to complete. In total, 545 questionnaires were recovered, of which 30 were excluded due to incomplete information or incorrect filling, and 515 were valid questionnaires, with a recovery rate of 94.50% (The sample distribution is shown in Figure 1). The other part of the data concerns built-up environmental accessibility, which researchers on the spot measured. The researchers used the Ovitalmap to measure the distance from the sample households to the market, health center, bus station, main road, older adult activity center, square (park), supermarket (canteen), village committee, kindergarten, primary school, town center and other destinations in the sample village.

2.2 Variables

The dependent variable was subjective well-being, using the Memorial University of Newfoundland Scale of Happiness (MUNSH). MUNSH is a commonly used self-rating scale of the subjective well-being of older adults, developed by Kozma and Stones (46). MUNSH has 24 items reflecting positive emotion (PA), negative emotion (NA), positive experience (PE), and negative experience (NE). The final score of the SWB was calculated. The calculation formula is as follows:

$$SWB = PA + PE - NA - NE$$

Independent variables included walk accessibility, socio-demographic information, built environment perception and preferences, and physical activity information. The demographic variables mainly included gender, age, marital status, education level, resident population status, and health status. Among the respondents, 194 (37.7%) were male and 321 (62.3%) were women; 121 (23.6%) aged 60–65 years, 143 (27.8%) aged 66–70 years, 103 (20.0%) aged 71–75 years, 70 (14.1%) aged 76–80 years, 66 (12.8%) aged 81–90 years, and 8 (1.7%) aged over 90 years. The demographic information of the respondents is shown in Table 1. Subjectively perceived variables were road conditions, safety near the residence, travel convenience, and walking preference. Road conditions were measured by six items, safety near residence was measured by seven items, four items measured travel convenience conditions, and walking preference was measured by one item (See the attached table for the specific question

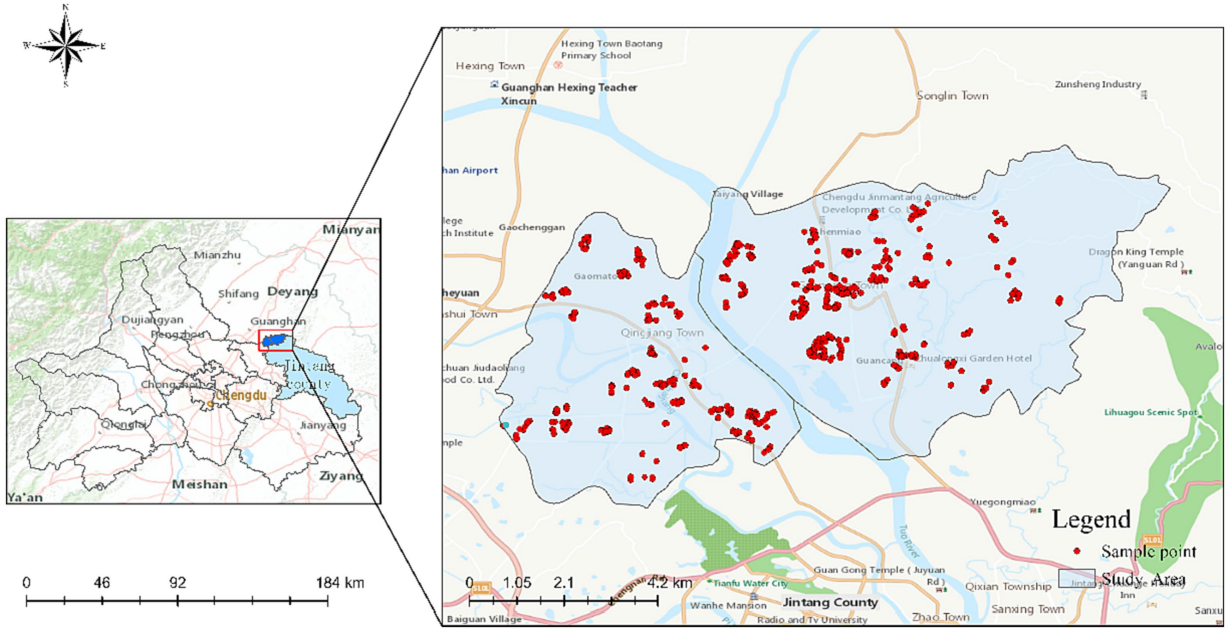

FIGURE 1
Sample distribution map.

TABLE 1 Demographic information.

Population basic information category	Variable type	Variable-definition		Amount	Percent (%)
Gender	Classified variable	Male	Gender1	194	37.7
		Female	Gender2	321	62.3
Age	Sequence variable	60–65	Age1	121	23.6
		66–70	Age2	143	27.8
		71–75	Age3	103	20.0
		76–80	Age4	70	14.1
		81–90	Age5	66	12.8
		>90	Age6	8	1.7
Education	Sequence variable	No	Education1	228	44.3
		Elementary school	Education2	229	44.5
		Junior middle school	Education3	48	9.2
		Senior middle school	Education4	8	1.6
		University and above	Education5	2	0.4
Marriage	Classified variable	Married	Marriage1	412	80.0
		Unmarried	Marriage2	102	20.0
Physical condition	Sequence variable	Good health	Health1	45	8.7
		Relative health	Health2	263	51.1
		Normal health	Health3	123	23.9
		Bad health	Health4	72	14.0
		Worse health	Health5	12	2.3

items). The five-point Likert scale defines all the items. Walking accessibility in this study was measured on-site by researchers using the Ovitalmap. The data calculation process referred to a study by Ao et al. (47). The calculation formula is as follows:

$$\text{Accessibility} = {}^{1}\!\!\diagup\!\!{}_{d_n + 1}$$

2.3 Method

The random forest (RF) model was used to explore the non-linear relationships between socio-demographic factors, subjective perception, walking accessibility, walking accessibility in daily behaviors, and older adults' subjective well-being in rural areas. The random forest model is a machine-learning algorithm based on an integrated learning framework. It works by creating multiple decision trees and making predictions based on the majority votes of all single trees, as is shown in Figure 2. Random forest has been widely used in constructing the environment, transportation, and other fields (29, 36, 48). Compared with traditional linear models, the random forest has better predictive performance on model selection, suitable for different types of explanatory variables (continuous and discrete), and has good flexibility, generalization, and resistance to overfitting.

However, the random forest model is inferior to the conventional linear model in terms of interpretability, known as the black-box problem in the field of machine learning. To address this problem, various methods of interpreting machine learning have emerged, such as locally interpretable model-agnostic interpretation (LIME), cumulative local effects (ALE), partial correlation maps (PDP), and SHAP. In this study, we introduced the PDP method for visualizing the nonlinear relationships and importance assessment between the explanatory and dependent variables. The PDP explains the model by demonstrating the marginal effect of the feature variable on the dependent variable, avoiding reliance on *a priori* assumptions. We will use the PDP to demonstrate the nonlinear relationship of independent variables on subjective well-being in rural older adults (49, 50).

$$\hat{\phi}(X_1) = \frac{1}{T}\sum_{i=1}^{T} f(X_1, X_{i2}, \ldots, X_{ij})$$

In the formula, the dependent variable is $f(x)$; $\hat{\phi}(X_1)$ is the partial correlation function of the feature variable X_1; T represents the number of instances in the data set; $X_1, X_{i2}, \ldots, X_{ij}$ is the actual observation of the j th feature of sample i.

In conclusion, this study will use random forest models and explanatory machine learning methods to deeply explore the socio-demographic factors, subjective perception, walking accessibility, and the nonlinear relationship and characteristic importance assessment of daily behavioral walking accessibility and the subjective well-being of rural older adults. By applying this method, this study will provide helpful information for understanding rural older adult travel and provide scientific support for improving travel planning and neighborhood environment design.

In the process of optimizing the random forest model, three core parameters are mainly adjusted: the maximum tree depth, the number of features of a single tree, and the total number of trees. A grid search

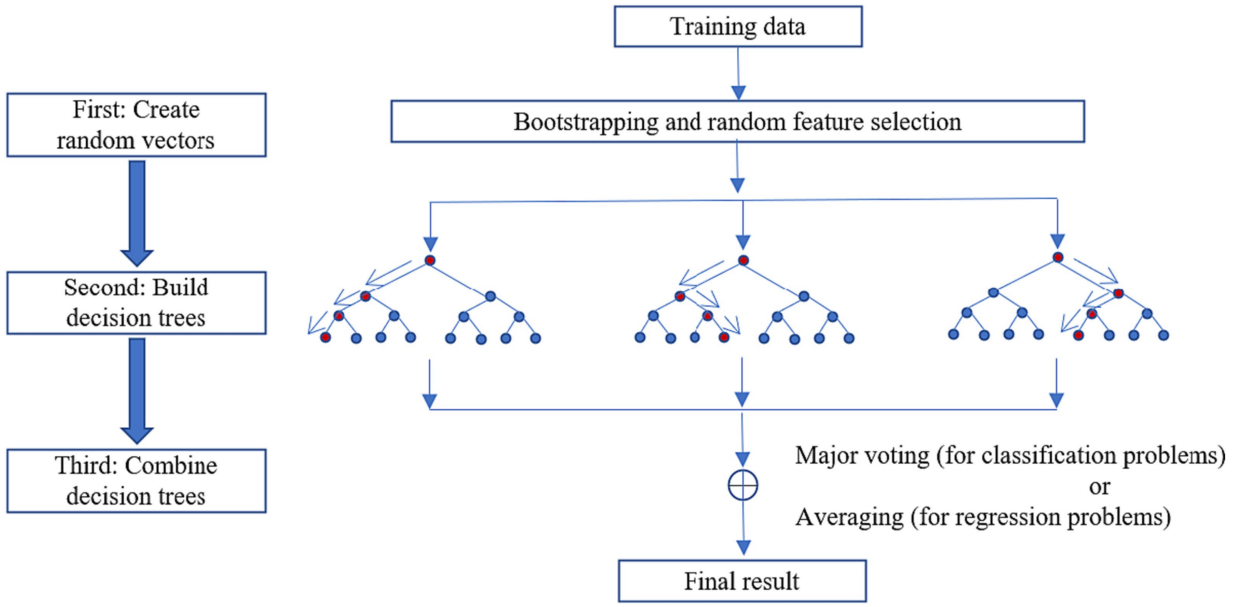

FIGURE 2
Schematic representation of the random forest.

technique is introduced to find out the optimal combination of these parameters, and arbitrary settings of the parameters are avoided (51). The grid search process is as follows: first, set the parameter range, the maximum depth of the largest tree is 1–20, the number of single tree features is 2–10, and the number of trees is 10–1,000 (interval 10). Then, all 18,000 (=20 × 9 × 100) possible parameter combinations were evaluated to test the model performance by out-of-bag error (52). After 18,000 tests, it was found that the model showed the best performance when the maximum depth was set to 6, the number of features was set to 9, and the total number of trees was set to 210. Therefore, this parameter combination was chosen as the optimal model, and a subsequent analysis was performed.

3 Results

3.1 Relative importance of the independent variables

Table 2 and Figure 3 shows the relative importance of the independent variables in predicting subjective well-being among rural older adults; the higher the relative importance, the more significant the ability of the independent variable in the prediction. Notably, walking accessibility had the highest overall contribution of all the independent variables. This finding not only confirms previous research findings but also highlights the importance of walking accessibility in the subjective well-being of older adults in rural areas (36, 53, 54).

Furthermore, subjective perceived variables were studied in depth, focusing on the effect of safety of residence and other factors on subjective well-being among rural older adults. In terms of subjective perceived variables, the safety of residence was identified as the most critical factor in predicting subjective happiness, with a contribution rate as high as 7.39%, which highlights the vital importance of community security for the life satisfaction of older people, because, in rural areas, community safety conditions may affect the social activities, travel habits, and overall quality of life of older adults. On the other hand, in the socio-demographics category, the relative importance of health status was relatively high, reaching 6.06%, and that of age also reached 5.05%. This finding suggests that health status and age play an essential role in the subjective well-being of rural older adults. It is worth mentioning that the relative importance of marital status, education level, and gender was low, all contributing less than 1%. Perhaps in rural areas, these factors have relatively weak effects on older adults subjective well-being.

3.2 Non-linear effects of the independent variables on the SWB

In this section, random forests are used to generate partial correlation maps (PDP) to more intuitively demonstrate the non-linear relationship between walking accessibility and the subjective well-being of rural older people. Figures 4–6 show the partial dependency plots generated for each variable of the random forest model, with the *x*-axis representing the distribution of independent variables and the *y*-axis representing the subjective well-being of rural older adults. To reduce noise and better describe the relationship between the independent and dependent variables, smooth curves were drawn using the Scipy library in Python (55). The data from the partial dependency plots showed that most walking accessibility factors showed non-linear and threshold effects in terms of subjective well-being in rural older adults.

Figures 4, 5 show that rural older adults' subjective happiness initially decreases with increasing market accessibility. However, when accessibility reached 0.2411, happiness began to plateau and remained relatively flat. However, once the market accessibility exceeded 0.4107,

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TABLE 2 Relative materiality.

	Variable	Relative importance (%)	Total (%)
Walking accessibility	Market Accessibility	5.19	52.25
	Health Centre Accessibility	4.25	
	Bus Stop Accessibility	5.05	
	Main Road Accessibility	4.85	
	Older adult Activity Centre Accessibility	4.12	
	Square Accessibility	4.05	
	Supermarket Accessibility	6.77	
	Village Council Accessibility	4.86	
	Kindergarten Accessibility	4.18	
	Primary School Accessibility	4.13	
	Town Centre Accessibility	4.79	
Subjective perception	Traveling road conditions	5.65	23.49
	Convenience of transport	3.78	
	Level of safety near home	7.39	
	Walking preference	6.67	
Socio-demographics	Gender	0.65	15.65
	Age(years)	5.05	
	Marital Status	0.69	
	Education level	0.94	
	Living style	2.26	
	Health Status	6.06	
Daily behavior	On average, how long do you sit and do these activities each day?	2.54	8.61
	How long do you walk on average per day?	1.09	
	How long do you spend doing housework each day?	2.02	
	On average, how long do you spend relaxing in your chair each day?	2.96	
Total relative importance			100

the subjective happiness of older adults began to decline again. This trend is also equal between health center accessibility and subjective well-being.

As for the accessibility of destinations such as older adult activity centers, village committees, primary schools, and town centers, the trend is quite consistent. As the accessibility in these places increases, the subjective happiness of the rural older adults gradually increases, then stabilizes within a certain range, and then rises again. In contrast, the effect of accessibility at bus stops and kindergartens on subjective happiness showed a pattern of increasing first and then stabilizing. In particular, it is noteworthy that kindergarten accessibility has a significant threshold effect on subjective well-being, which will reach the threshold once the accessibility reaches 0.5957.

Furthermore, plaza accessibility increased within the accessibility from 0.1890 to 0.2976, leading to a rapid rise in subjective happiness. However, once accessibility exceeded 0.2976, subjective happiness began to decline. Similarly, supermarket accessibility showed a similar trend, with happiness gradually decreasing with increasing accessibility, reaching a threshold at 0.7376, after which happiness stabilized. The accessibility of the main road was relatively stable in the range of 0.2821 to 0.7044. However, subjective happiness began to decline sharply when trunk road accessibility exceeded 0.7044.

Figure 6 illustrates key variables associated with subjective well-being in rural older adults and other influencing factors besides walking accessibility. The clear nonlinear relationship between these critical variables and subjective well-being in rural older adults corresponds with the original study's expectations. It can be observed from the partial dependence chart that the key variables such as safety, road conditions, walking preference, and travel convenience all have a positive impact on the subjective happiness of older people in rural areas with the increase of independent variables. This trend implies that older adults' subjective well-being increases as these factors improve. However, it is worth noting that different relationships exist between age and subjective well-being in rural older adults. Between the ages of 50 and 69, the trend in older adult subjective happiness increased slowly but remained relatively stable. However, after reaching age 69, subjective well-being began to decline gradually, suggesting a threshold effect at some age stage, after which subjective well-being gradually decreases with age.

4 Discussion

To have a deeper understanding of the factors that affect the happiness of older people in rural areas to improve their quality of life,

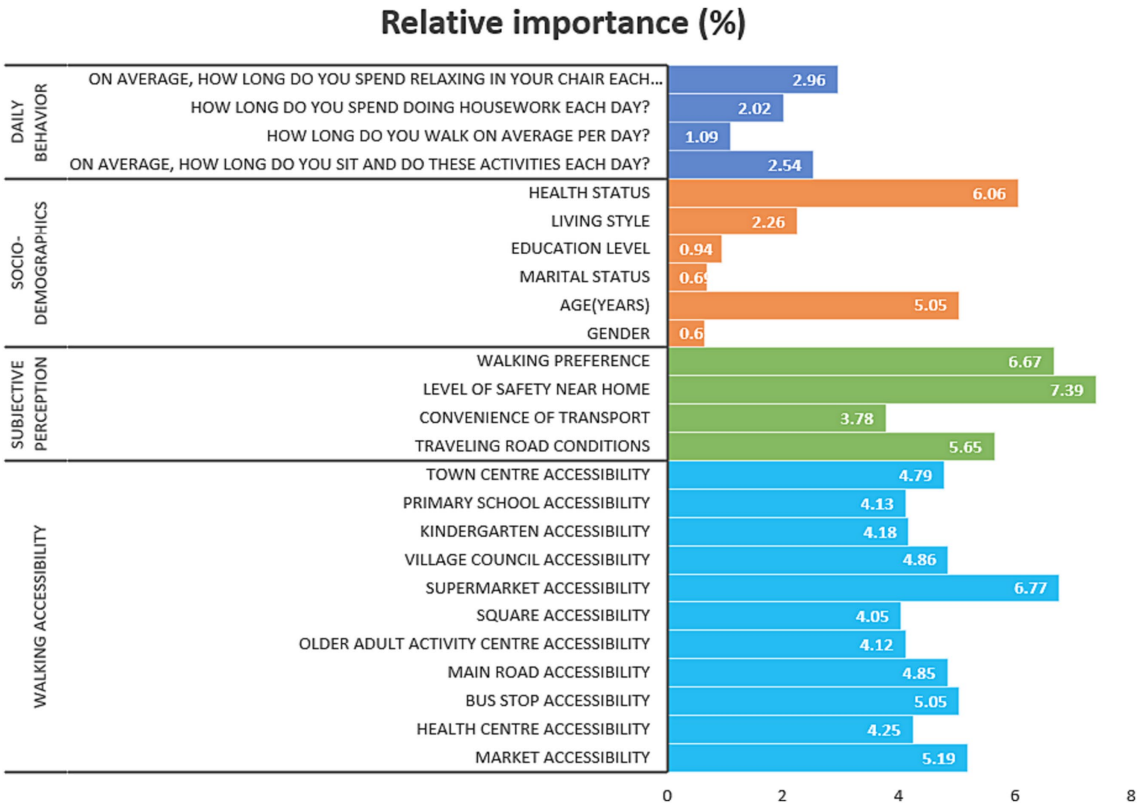

FIGURE 3
Relative importance.

we chose Jintang County of Chengdu City as the research object to carry out research in 11 sample villages. We explored the nonlinear relationship between walking accessibility and subjective well-being in rural older adults. Using the random forest model, the following conclusions were gained:

First, walking accessibility had the highest overall importance for the subjective happiness of rural older adults, reaching 52.25%. The walking accessibility of different destinations has different effects on the subjective happiness of rural older adults, as Xu et al. (56), with consistent results. With the improvement of market and health center accessibility, the subjective happiness of rural older adults will show a decline, stable, and then decline. This trend can be explained in terms of real-life conditions and psychological factors. When the market accessibility increases, it may bring some adverse effects. As known from the research by Delbosc (57), such as traffic congestion, noise, and so on, which may make them feel inconvenient and dissatisfied, thus reducing their happiness. Similarly, accessibility to health centers may show a similar trend, with initial improvements that may mean better healthcare access, but excessive accessibility may not further increase happiness and even cause excessive worry or discomfort. These conditions may explain why, within a specific range, increased accessibility improves well-being, but either too high or too low may lead to decreased well-being. This finding also highlights the importance of balancing various factors to enhance the happiness of older people. In conclusion, some suggestions can be made for rural areas to help improve the subjective well-being of older people in rural regions. First, attention should be paid to improving walking accessibility to provide more convenient travel conditions, thus increasing the opportunities for interaction and activities between older people and the community. Secondly, strengthen the safety measures in the community, improve the sense of security of older adults, and create a comfortable and secure living environment for them. In addition, focusing on the health status of older adults and providing health care and health services can help to improve their quality of life and happiness. Finally, given the impact of age on subjective happiness, society can meet their needs by holding activities suitable for different age groups to improve their overall satisfaction. These suggestions take into account the reality and needs of older adults in rural areas and improve subjective well-being by improving their living environment, security, health status, and social activities.

In terms of accessibility to destinations such as older adult activity centers, village committees, primary schools, and town centers, the trend of subjective well-being is relatively consistent and generally gradually increased. This finding echoes the research of Lättman et al. (58), which indicates that accessibility is related to both travel satisfaction and life satisfaction among the older adults. Sites such as older adult activity centers, village committees, and town centers often provide opportunities for social interaction and cultural activities, so with increasing accessibility, the rural older adult may be more likely to participate in these community activities. According to Onishi et al. (59), this participation enhances social support and interaction, thereby enhancing well-being. Within a certain range, the increased accessibility makes it easier for older adults to integrate into community life and enjoy more social support and interaction. Increased accessibility at bus stops may mean that it is easier for older people to travel to different destinations, increasing their range of activities and social opportunities

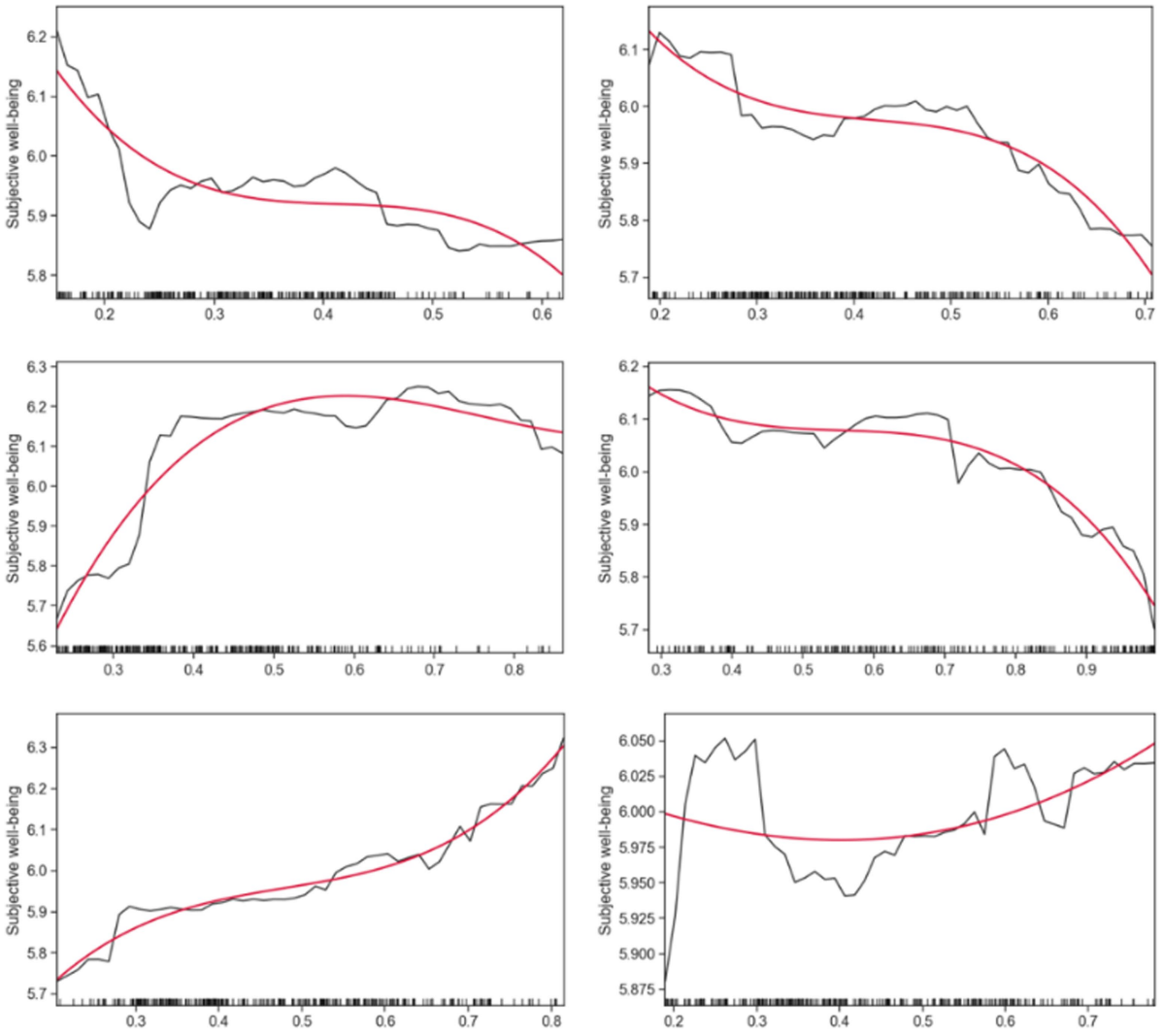

FIGURE 4
Nonlinear effects of walking accessibility on subjective well-being.

and enhancing happiness. The study by Zhu et al. (60) reflects that the most crucial factor affecting the well-being of older adults is the distance from home to high school. Regarding the accessibility of kindergartens and primary schools, its impact on happiness might be linked to the role of older adults within the family. Older adults play a crucial role in cultural inheritance and the structure of the family (61). Therefore, convenient access to schools enables them to more easily visit their grandchildren or participate in school activities, which could enhance their sense of happiness. However, the noise and crowding around schools might negatively affect some older adults. For square accessibility, the rapid rise in happiness may be because these sites often provide a social gathering place or shopping center, allowing rural older adult to participate in social activities or shopping, thus enhancing their emotional satisfaction. However, once accessibility exceeds a certain degree, it may lead to excessive crowding and noise, thus reducing well-being.

Finally, the key variables such as safety near home, road conditions, walking preference, and travel convenience positively impact the subjective happiness of older adults in rural areas with the increase of independent variables. Probably because they are directly related to the quality of life and everyday experiences of older people. Safer and more convenient roads can reduce older people's travel pressure and insecurity (62). Similarly, increased walking preferences may enhance social interaction and daily activities, enhancing well-being. The different relationship between age and subjective happiness may be because older people at different age stages face different life needs and psychological states. Older people aged 50 to 69 are likely to be more active, with more social interactions and daily activities, leading to a more positive sense of well-being compared to those aged 70 and over. However, a threshold effect at age 69 may occur, possibly because a gradual decline in physical condition and decreased social circles affect well-being. Aging with increasing physical health and social interaction limitations may lead to a progressive decrease in subjective well-being (63).

In conclusion, this study analyzed the relationship between walking accessibility and the subjective well-being of rural older adults using a random forest model by investigating Jintang County in Chengdu. The study found that walking accessibility had an important

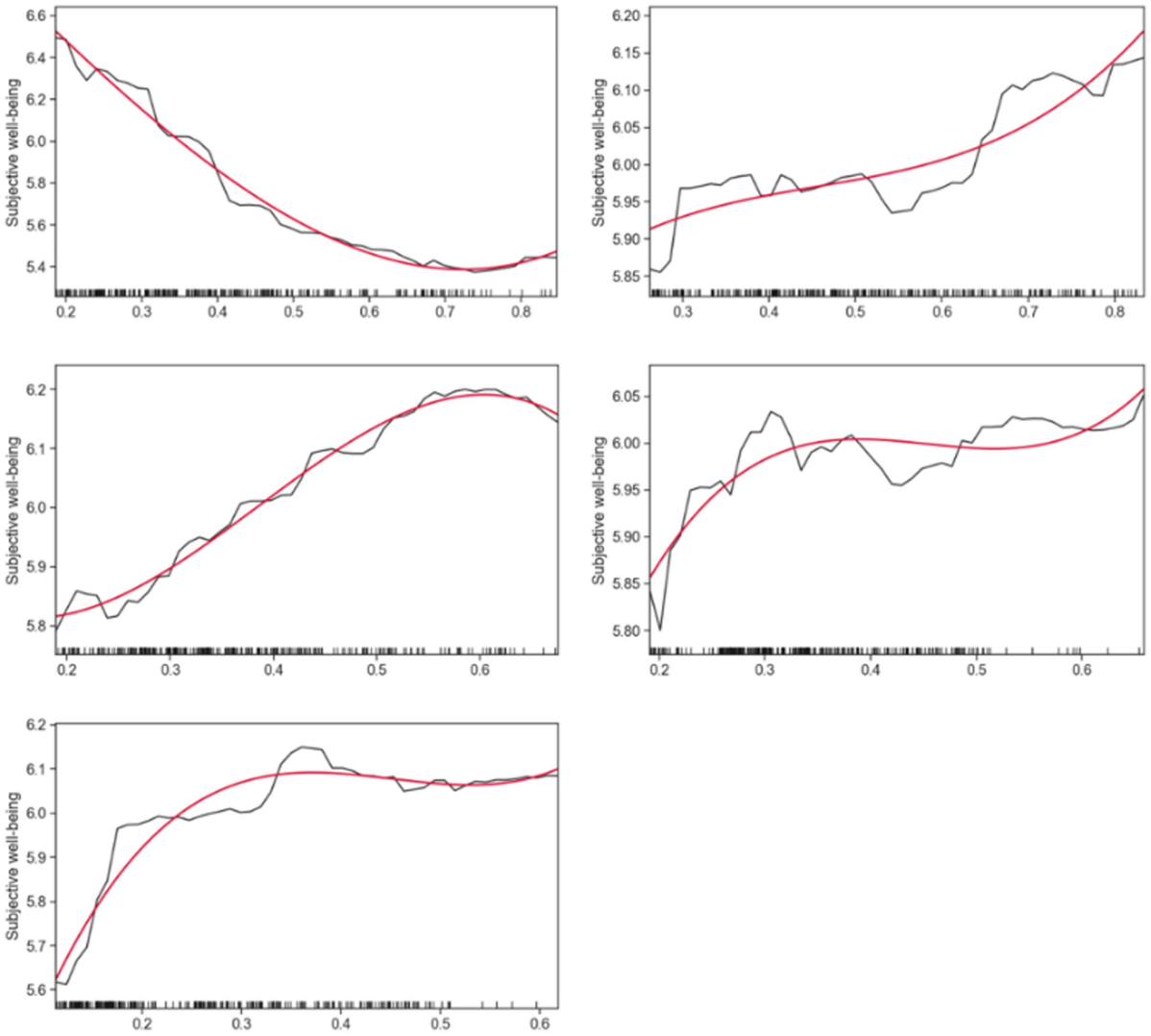

FIGURE 5
Nonlinear effects of walking accessibility on subjective well-being.

impact on well-being, and accessibility at different destinations had different effects on happiness. In addition, factors such as residence safety, travel road conditions, walking preference, and travel convenience also positively impact the subjective happiness of rural older adults. There are differences in the effects of age on well-being, and increasing age may lead to a gradual decrease in well-being. These findings provide important references and enlightenment for improving the quality of life of rural older adults.

5 Conclusion

This study investigated the relationship between walking accessibility and subjective well-being in rural older adults. The results show that walking accessibility plays a vital role in affecting the happiness of older adults, especially the accessibility of markets and health centers, which offers non-linear and threshold effects. At the same time, community safety, travel road conditions, walking preference, and other factors also positively impact happiness. Age and age differ in happiness trends, with some variables showing clear nonlinear relationships. Based on the above research content and results, at the same time, the rural situation and the older adult living habits, the study puts forward the following suggestions to improve the quality of rural older adult life and happiness and help the government, community, and related agencies to take targeted measures to meet the needs of older adults, improve their life satisfaction and happiness:

1. Improve walking convenience: In rural areas, the development of public transportation may be limited, so improving walking convenience is a feasible approach. The government can invest in improving the roads and sidewalks in the village to ensure that it is easy for older adults to go to markets, health centers, and other places. At the same time, resources in rural areas are relatively limited, so it can be considered to build multi-functional activity places, such as activity centers for the older

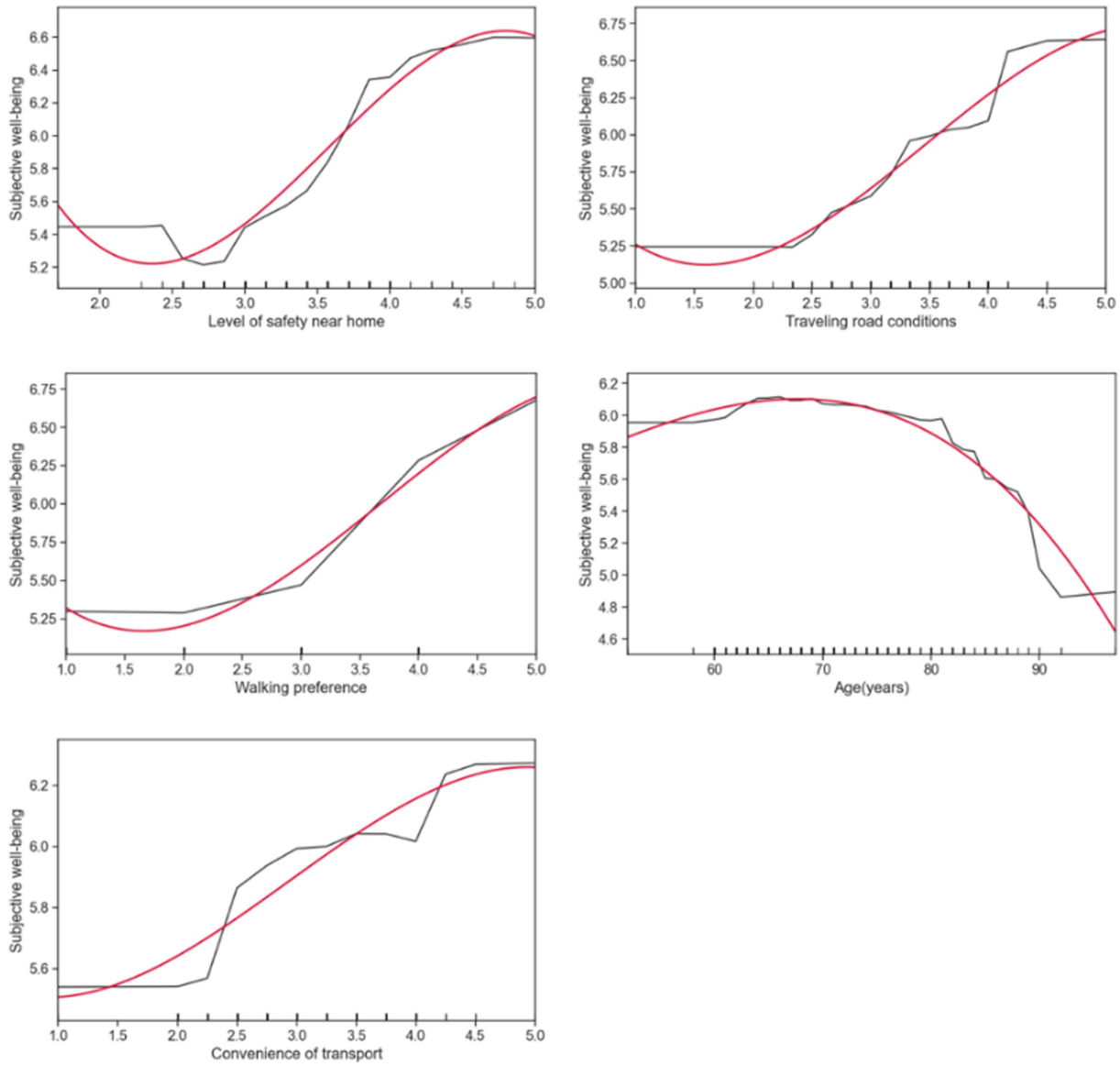

FIGURE 6
Nonlinear effects of walking accessibility on subjective well-being.

adult, for the older adult to have leisure, social, and fitness activities to enhance happiness further.

2. Strengthening community policing and patrols: security issues may affect the well-being of older adults. Strengthening community patrols and policing to improve the sense of security in the community can make older people go out more at ease. Moreover, interpersonal relationships are closer in rural communities. Encouraging older adults to participate in community activities and cultural inheritance and enhancing community cohesion will help to improve their happiness.
3. Focus on health promotion and support: Due to the limited medical resources, the government and the community can strengthen health promotion, provide basic health knowledge, and encourage older adults to adopt a healthy lifestyle.

These recommendations are based on realities and fully consider resource constraints and characteristics in rural areas to ensure the rationality and feasibility of implementation. By considering walking accessibility, community safety, health support, and social interaction, we can create a better living environment for rural older adults and improve their happiness and quality of life.

Data availability statement

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

Ethics statement

Ethical review and approval were not required for the study involving human participants in accordance with the local legislation and institutional requirements. The patients/

participants provided their written informed consent to participate in this study.

Author contributions

HL: Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Software, Validation, Writing – review & editing. ML: Conceptualization, Data curation, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. PP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Visualization, Writing – original draft, Writing – review & editing. YL: Methodology, Software, Visualization, Writing – original draft. YA: Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Validation, Writing – review & editing. HB: Writing – review & editing.

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Conflict of interest

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

Publisher's note

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Appendix

TABLE A Variable description.

Travel road conditions	1. Travel has very good sidewalks.
	2. Travel has very nice bike lanes.
	3. Travel has a very good motorway.
	4. Convenient access to the public transit station.
	5. Travel to the destination is convenient and direct.
	6. Public facilities maintenance and service is very good.
Security degree near the place of residence	7. The trip process is very safe.
	8. The road to travel is broad.
	9. The road is smooth.
	10. There is no burden during the trip.
	11. There were no traffic accidents near my home.
	12. Daily necessities can be bought over a short range.
	13. No crime has occurred near the residence.
Travel convenience	14. Motorcycle riding is fast and convenient.
	15. Cycling is fast and easy.
	16. It is convenient and easy to take a travel tricycle.
	17. Other modes of travel (except bus, battery car, motorcycles, bicycles, walking and tricycles) are convenient and fast.
Walking preference	18. I like walking.

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Influencing factors of health screening among retirees: an extended TPB approach

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Background: Health screenings are promoted worldwide as they help detect and prevent overall health issues. Despite expanding coverage, the participation rate among the retired population has not significantly increased. Given the special role of health screenings in promoting health and healthy aging, understanding the behavioral intentions, and influencing factors of retirees' voluntary participation in health screenings is crucial. This study aims to explore the participation intentions in health screenings among the Chinese retired population by integrating the Theory of Planned Behavior (TPB) and Self-Efficacy (SE).

Methods: This study used a cross-sectional design to conduct an online questionnaire among 311 retirees in 2023. The questionnaire, tailored for the Chinese retired population, combines the TPB theory and Self-Efficacy theory, including demographic structure, the basic structure of TPB, and SE.

Results: A Structural Equation Modeling (SEM) approach was used to identify factors related to health screening behaviors. Of the respondents, 311 completed the survey (88.9% response rate). The most crucial determinant of health examination behavior was behavioral intention, with a correlation score of (1.524, $p < 0.001$). Significant correlates of behavioral intention included Subjective Norms (SN) and Self-Efficacy (SE), followed by Perceived Behavioral Control (PBC) and Attitude (AT), with correlation scores of (0.401, $p < 0.001$), (0.339, $p < 0.001$), (0.082, $p < 0.001$), and (0.060, $p < 0.05$), respectively.

Conclusion: This study provides insights for enhancing the willingness and behavior of retirees to participate in health screenings.

KEYWORDS

health screening, the theory of planned behavior, self-efficacy, participate behavior, retirement

1 Introduction

Health screening helps to detect and prevent the overall health of individuals, and maintaining good physical health can improve the quality of life of individuals and enhance psychological and social well-being (1). Health screening refers to the practice of checking disease indicators before symptoms appear. A considerable proportion of health screening in China are offered as packages—often including X-rays, ultrasound, CT, and an extensive array of tumor markers and genetic tests (2). In China, although health screening coverage has expanded over the past decade, most potential beneficiaries remain unscreened and

underserved (3, 4). Population aging is the new normal for society in this century (5). With the continuous development of the social economy, retirees' health and well-being are affected by income, free time, social roles, and life partners of life (6–8). Given the unique role that health screening plays in promoting health and healthy aging, it is crucial to understand the behavioral intentions and factors influencing voluntary participation in health screening among retirees. Previous research has explored the importance of Health screening from different perspectives, including community health centers, urban populations, rural populations, lifestyle interventions (9–12), and disease screening (13–15). Many retirees were not fully aware of the benefits of health screening to themselves and their families. They believed that there was a low risk of acquiring underlying diseases and getting sick, so they did not need to attend health screening. A lack of awareness of health screening was a major reason why people did not participate.

The Theory of Planned Behavior (TPB) theoretical framework is often used to explain behavioral intentions and has been widely applied to health behavior (16). Its essence is a social cognitive theory of decision-making processes, considered an effective theoretical framework for behavioral guidance. In the context of health behavior, retiree participation in Health screening behavior (PB) is essentially determined by participation intention (PI); among them, PI is influenced by the attitude of whether to participate in health screening (AT), the opinions of people around retiree about health screening (SN), and the individual's decision to participate in health screening (PBC). The theoretical framework provides a promising avenue for understanding retirement groups' behavioral intentions and behaviors in Health screening. A large number of studies (17–19) proved that TPB can successfully predict health behaviors and found that TPB can effectively predict different types of Health screening behavior (20, 21). Therefore, the purpose of this study was to investigate the psychological factors related to health screening intentions among Chinese retirees and to understand retirees' participation intentions and motivations, which could help improve the examination rate. We hypothesized the applicability of TPB in explaining the role of Chinese retirees participating in health screening.

Along with the TPB model, many studies have combined SE for discussion; SE is another important decision-making factor that predicts health behavior (22–24). Researchers have found that self-efficacy positively impacts one's intention to engage in activities and effectively increases the likelihood of that behavior. It is a strong health predictor as it affects patients' certainty about their ability to perform recommended behaviors to improve their health. These findings have been demonstrated in various area studies relating to health behavior (25–27). The contributions of this study are as follows.

Previous research mainly focused on health screening in the clinical field or big data screening in public health. This study predicts the participation intention of current health screening and the influencing factors of participation behavior from the perspective of personal psychology and behavior. Then, this study adds SE to the TPB theoretical framework and verifies the feasibility of the TPB extended model in the health screening behavior of retired people. Finally, this study demonstrates the inherent mechanism between the four prediction dimensions. Through the analysis of 311 valid questionnaires, it explores the influencing mechanism of retirees' willingness to participate in physical examinations, aiming to help decision-makers formulate relevant policies and regulations and provide Practitioners provide reliable project design guidance. And more clearly identify participants' participation intentions and participation status from a practical perspective.

The remainder of this paper is organized as follows. Section 2 examines the literature on the TPB and SE and explains the theoretical background. Additionally, we propose several hypotheses. In sections 3 and 4, we describe our data and present the descriptive statistics. Section 5 analyzes the research results and the limitations and suggestions. Finally, Section 6 provides a conclusion highlighting future research implications.

2 Literature review

2.1 Theory of planned behavior

The theoretical framework of this study was adapted from the TPB. They propose that an individual's intention to engage in a specific behavior is the strongest predictor of that behavior (16). The relationships between these factors (AT, SN, and PBC) in the TPB model all have been supported when applied to different health behaviors. Such as McEachan's review of the literature discussing health-related behaviors surveyed 206 papers using the TPB theory, and the authors concluded that TPB was a good predictor of health behaviors (28). Moreover, the TPB has also been used as a theoretical framework for designing health behavior interventions, including promoting physical activity (29) or protect oral health (30). They expand the explanatory power of TPB.

In addition, based on the TPB model, most studies of participation in Health screening intention or behavior focus on cancer screening for men or women. For example, one study found women's promotion of cervical cancer screening rates (31), Sun's studies in rural women's willingness to participate in breast cancer (32), and Sieverding's research men—participation in prostate cancer screening (33). The authors found that TPB use and Health screening in retirees have not been studied. Therefore, this research aims to explore the feasibility of using the TPB theory to investigate the participation of retired individuals in Health screening in China.

2.1.1 Attitude toward the participate intention

Attitude (AT) reflects an individual's evaluation of performing health screening, seen as either positive or negative (34, 35). This concept suggests that attitudes toward specific health behaviors, such as cancer screenings, significantly influence participation, 2023; Sun et al. (31, 32). Research in retired populations indicates that attitudes can predict engagement in activities like sports (36) and influence intentions to seek mental health help (37). A study on older adults with hearing loss highlighted that those positive attitudes toward their condition encouraged health-seeking behaviors (38). Thus, AT is thought to involve intentions to undergo health screenings, associated concerns or emotions, and the belief in the health benefits of health screenings.

2.1.2 Subjective norm toward the participation intention

Subjective norms (SN), reflecting perceived social pressure, significantly influence health behavior intentions. Studies indicate SN's strong impact on specific health actions, with norms categorized

into descriptive (observing others' actions) and injunctive (beliefs about what significant others think one should do) (39–41). Yap found that higher perceived social pressure increases the intention to participate in health screenings (42). Similarly, recommendations significantly affect decisions like HPV vaccination among young women (43) and seeking cancer help among retired men (44). Chang's study highlighted the media's role in shaping behaviors like hearing aid use among the older adult (45). In our study, retirees' health checkup decisions were influenced by significant others, with family, friends, and authority figures playing crucial roles in their choices. Online information also impacts their perceptions and decisions regarding health screenings.

2.1.3 Perceived behavioral control toward the participation intention

Perceived behavioral control (PBC) reflects an individual's belief in their capability and control over actions, influencing the ease of performing behaviors (34). Recognized as a critical health asset, PBC correlates with health behavior intentions and actions (46, 47). Studies show PBC linked to behaviors like responsible drinking (48) and parental actions to prevent children's myopia (49). In type 2 diabetes management, PBC significantly influences treatment participation, with patients more willing to undergo injections believing in better disease control (20, p. 2). Others highlighted PBC's role in mitigating aging-related declines (50) and in promoting physical activity among older adults (32, 51). This study posits that retirees' PBC affects their decision and ability to engage in health screenings.

2.1.4 Participation intention and behavior in health checks

Understanding the role of intention in participating in health behaviors is critical, as it directly affects participation in health Screening. Intention has been proven to be a direct determinant of behavioral orientation in the mental health management of the older adult (52), diabetic patient care (53, 54), and oral health (55). Literature on CCS health screenings indicates intentions can account for behavioral differences (56). However, intentions do not always result in actions, as seen in a study on older adults with osteoarthritis in Portugal, where intention had little effect on physical activity (57). The participation intention we discuss in this study is the degree of readiness to perform health screening behaviors, which can include positive and negative attitudes and is influenced by the advice of significant others.

2.2 Self-efficacy toward the participation intention

Self-efficacy, reflecting confidence in managing health outcomes and perceived health competence, strongly predicts health behaviors (58, 59). It is linked to behaviors that improve older adult health (60, 61)and influences life satisfaction (62), community health activity engagement (63), and health management (64, 65). Schwarzer highlighted that action self-efficacy predicts preventive health actions in the older adult (66). Retirement impacts seniors' health behaviors, with high self-efficacy post-retirement enhancing health actions, such as increased smoking cessation rates among retirees (67, 68). Leisure self-efficacy also improves retired individuals' quality of life (69). Despite these findings, the causal link between self-efficacy and behavior requires further exploration (70). This study examines self-efficacy as a predictor of retirees' engagement in preventive health measures, specifically in health screening participation, including planning and adherence to health screening activities.

2.3 Development of hypotheses

This research examines the influence of retirees' internal determinants on decision-making and participation in health screening activities. We put forward two research questions:

RQ1: What specific reasons influence retirees' voluntary participation in Health screening?

RQ2: To what extent do these factors influence the likelihood of retirees voluntarily engaging in health screening behaviors?

These two research questions aim to identify factors contributing to voluntary participation in health screening among retired individuals. Additionally, they seek to determine how these factors impact retirees' intentions to participate in Health screening voluntarily. These research questions are essential as they assist practitioners or policymakers in better serving retired individuals and addressing the challenges associated with the aging population.

Based on the TBP model and prior studies, the following hypothesis was proposed:

> *H1*: The AT of retirees toward health screening positively correlates with their willingness to participate in Health screening.
>
> *H2*: The SN of retirees regarding health screening positively correlates with their willingness to participate in Health screening.
>
> *H3*: Retirees' PBC to participate in health screening and intention to participate are positively related.
>
> *H4*: Retirees' SE to participate in health screening and intention to participate are positively related.
>
> *H5*: Retirees' PI in Health screening and the PB of the retirees are positively correlated.

Based on the above hypotheses, we could add new variables (SE) to the TPB model on a reasonable basis. The research examines survey data on the retired population's intentions to participate in Health screening and will relate influencing factors. Combined with the existing literature, the research hypotheses and the model adopted in this study were developed based on TPB, shown in Figure 1.

3 Methods

3.1 Instrument

To test the above hypothesis (Figure 1), this study used multi-item scales to measure each variable, which provides better stability and minimizes measurement error. These well-established scales have been rigorously tested in numerous studies and have shown good reliability and validity. The measurement items of this study were

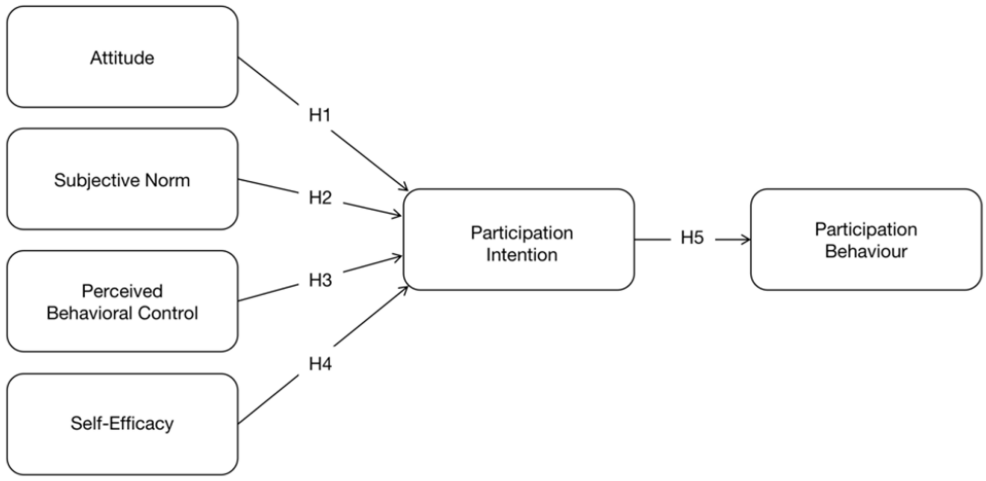

FIGURE 1
Participation behavior model based on TPB.

TABLE 1 Details of the employed TPB questionnaire.

Variables	Number of items	Sample of items	Sources reference
Attitude (AT)	4	The health screening will help me improve my health if I choose to participate in it.	(71, 72)
Subjective norm (SN)	4	When friends and I talk about health screening, it can make me want to go for one.	(31)
Perceived behavior control (PBC)	4	I can afford to pay for the health screening, and I will go for it.	(39, 73)
Participation intention (PI)	4	I participate in health examination in order to obtain a health report.	
Participation behavior (PB)	4	I have completed the health screening within the planned time.	
Self-efficacy (SE)	4	I am capable of staying healthy even if no one asks me to take a health examination, I do.	(25, 74, 75)

The constructs are measured using a five-point Likert scale, ranging from 1 (representing "strongly agree") to 5 (defining "strongly disagree").

evaluated and refined based on the previous research scale to ensure the validity and reliability of the content and to be more suitable for retirees' health screening behavior.

The TPB Measures include TPB structure and SE factor (Items are displayed in Table 1). The TPB structure is adapted from the TPB scale (71), and has been used in four previous research studies, Shumeli (72), Xin (31), and Dilekler (73), and Babazadeh (39): AT (Q6-Q9) refers to retirees' positive or negative emotional feedback on participating in health screening behavior, SN (Q10-Q13) refers to retirees are more likely to be influenced by other influential people when participating in health screening. PBC (Q14-Q17) refers to how retirees can decide how easy it is to participate in health screening. PI (Q22-Q25) refers to the direct motivation of retirees to participate in health screening. PB (Q26-Q29) refers to retirees' actual behavior of participating in health screening. In addition to the TPB construct, the questionnaire also included SE (Q18-Q21) as antecedents, which was adapted from the Measuring optimistic self-beliefs: A Chinese adaptation of the General Self-Efficacy Scale (75), Stout (74) and Dolatabadi (25), referring to the degree to which retirees feel confident in their ability to manage their health effectively. The measurement items consist of a total of 24 items, and the constructs are measured using a five-point Likert scale, ranging from 1 (representing "strongly agree") to 5 (defining "strongly disagree"). Likert scales assume that attitudes can be assessed, and that the degree of attitude lies on a linear continuum between strongly agree and strongly disagree. All items used in the questionnaire were translated into Chinese.

To ensure the questionnaire's content validity, we consulted a panel of experts, including three senior medical professionals specializing in health screening, two university lecturers with expertise in English, and two health educators. Their feedback was instrumental in finalizing the survey questionnaire.

3.2 Data collection

To meet the requirements of our study design, considering that we have 29 variables and following the principle that each variable requires at least 10 samples, we needed a minimum of 290 participants. To test the research hypotheses, we collected data from retired people in Shizong County, Yunnan Province. All data were collected between May and July 2023. An online questionnaire was generated on the platform with a unique web link. We used a screening question: "Have you reached retirement age or are preparing to retire? Are you willing to participate in this survey?" to exclude participants who do not meet the age standards and are unwilling to participate in the study to ensure that participants in the questionnaire meet China's retirement age Conditions include early retirement (45 years for women and 50 years for men) and mandatory retirement (50 years for women and 60 years

for men) (76). Through these procedures, a total of 350 questionnaires were distributed. After excluding invalid questionnaires with basically the same answers, logical errors, or response times of less than 15 s, 311 valid responses were obtained, and the overall effective questionnaire response rate was 88.9%. This study complied with the recommendations of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of Shizong County, Yunnan Province.

3.3 Ethical considerations

This study complied with the recommendations of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of Shizong County, Yunnan Province, ethics code/number: YNSZ-IRB-020-20230524.

3.4 Sample characteristics

As shown in Table 2, in the demographic analysis, the age group of 50–64 years had the highest number of participants in Health Screening, accounting for 47.91% of the total. The age group of 65–74 years accounted for 36.66%. Regarding gender distribution, females accounted for 45.02%, while males accounted for 54.98%. Regarding education, 45.98% had a high school education or below, 33.44% had a vocational education, 13.50% had a bachelor's degree, and 7.07% had a graduate degree or above. Regarding the participants' occupations before retirement, the highest proportion was observed among employees of state-owned enterprises and public institutions, accounting for 52.41%. Regarding monthly income distribution, 45.34% had incomes between 2001 and 5,000 yuan, while 42.77% had revenues ≤2000 yuan.

TABLE 2 Sample characteristics ($N = 311$).

Variable	Categories	Frequency	*N* (%)
Age	45–49	18	5.79
	50–64	149	47.91
	65–74	114	36.66
	Above 75	30	9.65
Gender	Male	171	54.98
	Female	140	45.02
Education	Up to secondary school	143	45.98
	College	104	33.44
	Undergraduate	42	13.50
	Graduate or higher	22	7.07
Occupation	Civil servants	62	19.94
	Employees of state-owned enterprises or public institutions	163	52.41
	Self-employed	60	19.29
	Unemployed	26	8.36
Monthly income	Under 2,000	133	42.77
	2,001–5,000	141	45.34
	5,001–10,000	34	10.93
	Above 10,001	3	0.96

3.5 Data analysis methods

This research employed structural equation modeling (SEM) to test the conceptual framework. We used SPSS 26.0 and AMOS 26.0 to analyze the main factors influencing retirees' participation in health examinations. Firstly, frequency analysis was conducted to determine the participants' general characteristics. Secondly, confirmatory factor analysis was performed using the AMOS 26.0 software to validate the dimensions and validity of the variable factor structure.

4 Results

4.1 Measurement tool assessment

4.1.1 Results of the reliability and validity test

This section uses confirmatory factor analysis (CFA) to examine the agreement between the five factors and the theoretical model. Total reliability (CR) and average variance extraction (AVE) evaluated the indicators' convergent and discriminant validity. AVE values >0.5 and CR values >0.7 are generally recommended (77). In this research, Cronbach's alpha values of all variables are above 0.7, indicating good internal consistency reliability. All variables' composite reliability (CR) values exceeded 0.7, indicating sufficient convergent validity (78). In addition, the AVE values of the six factors involved in this research (AT et al.) were all greater than 0.5, indicating that the scale data have excellent discriminant validity (Table 3). The results show that the scale has good reliability and validity.

4.1.2 Results of the reliability and validity test

Table 4 shows the results of the discriminant validity test. The square root values of the AVEs for all facets were higher than the inter-facet correlations, demonstrating sufficient discriminant power.

4.2 Assessment of the structural model and the hypotheses

4.2.1 Model fitting

In the first step of hypothesis testing, the structural model was evaluated. Our model shows a good fit for the data. The structural equation fit of the model was ($\chi^2 = 871.9$, df = 2,449, $p = 0.00$, CMIN/df = 3.502, NFI = 0.739, CFI = 0.797 IFI = 0.799, and RMSEA = 0.090). All fit index values were acceptable according to the established fit criteria (79).

4.2.2 Hypothesis testing and path size significance

This study calculated the path coefficient and p value through bootstrapping with a sample of 311 subjects. As shown in Table 4; Figure 2, all hypotheses are supported at a significant level of $p < 0.05$ or $p < 0.001$.

In this research, 311 retirees were surveyed, and the path coefficient and p value were calculated. As shown in Table 5; Figure 2, the intention-oriented hypothesis of participating in the health examination shows that the relationship between AT and PI is statistically significant when $p < 0.05$, showing a positive effect (0.060), which supports hypothesis H1. Secondly, the relationship between the

TABLE 3 The results of construct assessment.

	Mean	SD	SFL	CA	CR	AVE
AT				**0.853**	**0.901**	**0.694**
Q6 (AT1)	3.73	1.141	0.839			
Q7 (AT2)	3.81	1.095	0.82			
Q8 (AT3)	3.78	1.109	0.852			
Q9 (AT4)	3.92	1.087	0.821			
SN				**0.801**	**0.87**	**0.627**
Q10 (SN1)	3.84	1.074	0.782			
Q11 (SN2)	3.89	1.037	0.81			
Q12 (SN3)	3.89	1.022	0.792			
Q13 (SN4)	4.01	1.011	0.782			
PBC				**0.864**	**0.907**	**0.71**
Q14 (PBC1)	3.66	1.147	0.847			
Q15 (PBC2)	3.68	1.164	0.852			
Q16 (PBC3)	3.7	1.132	0.838			
Q17 (PBC4)	3.76	1.1	0.834			
SE				**0.818**	**0.879**	**0.645**
Q18 (SE1)	3.86	1.096	0.84			
Q19 (SE2)	3.91	1.017	0.775			
Q20 (SE3)	3.91	1.032	0.815			
Q21 (SE4)	4.03	0.967	0.782			
PI				**0.795**	**0.867**	**0.619**
Q22 (PI1)	3.66	1.124	0.798			
Q23 (PI2)	3.75	1.101	0.789			
Q24 (PI3)	3.71	1.089	0.777			
Q25 (PI4)	3.85	1.044	0.783			
PB				**0.812**	**0.877**	**0.64**
Q26 (PB1)	3.94	1.019	0.806			
Q27 (PB2)	3.93	1.003	0.791			
Q28 (PB3)	3.96	1.006	0.782			
Q29 (PB4)	4.04	1.028	0.82			

AT, Attitude; SN, Subject norm; PBC, Perceived behavioral control; SE, Self-efficacy; PI, Participate intention; PB, Participate behavior; SD, Standard deviation; SFL, Standardized factor loading; CR, Construct reliability; CA, Cronbach's alpha; and AVE, Average variance extracted.

three psychological factors (SN et al.) and the intention to participate in the behavior is statistically significant when $p < 0.001$, SN and SE have a significant effect on the PI had a significant positive effect (0.401 and 0.339). PBC had a positive correlation (0.082) with PI, supporting hypotheses H2, H3, and H4, respectively. Finally, PI has a significant positive correlation (1.524) to PB, so hypothesis H5 holds.

5 Discussion

This study investigated the relationship between retirees' intention to participate in health screening and actual participation by extending the TPB and incorporating SE. Research shows that the behavior of retirees to participate in health screening depends on their intentions and is directly affected by SN and SE. SN and SE significantly affect retirees' participation behavior, with participation intention as a mediator. PBC and AT have weak effects on retirees' intention to participate. All hypotheses in the model were supported, confirming that TPB is an acceptable theoretical basis for this study. This finding is consistent with previous TPB-based studies conducted in the United States (80), China (81, 82), and Europe (57).

This chapter discusses the theoretical and practical implications of our study in detail. Finally, we will also address the limitations of our study and provide recommendations for future research in this area.

5.1 Predictive factors

5.1.1 Predictive factors of intention for health screening

The results indicate that SN, SE, PBC, and AT positively impact retirees' intention to participate in health Screening.

The results found that SN is the most critical predictor of retirees' behavioral intention to participate in health check-ups, and it has the highest correlation with PI. This result echoes previous research that SN can well predict intentions in health behaviors (28) from the three aspects of social support, family support, and collectivism (31, 41, 54). It was also found that the external environment positively impacts SN (83), that is, the widespread use of social software and the accessibility of health information in the Internet environment. Social support in social networks is a significant health resource. High levels of social support are associated with better health behaviors and a greater intent to participate in health screening. This is further emphasized by the recent Chollou study (84).

This study confirms the feasibility of incorporating Self-Efficacy (SE) into the Theory of Planned Behavior (TPB), aligning with the views of Fishbein and Cappella that SE can better explain individual behavior within TPB (85). For instance, (86) found that blood donors with higher SE are more positively influenced by their participation experience. Similarly, Oikarinen noted in their study on the dietary habits of obese individuals that those with lower SE face more challenges in weight control (26), highlighting the importance of SE in self-care behaviors (87). In summary, within the TPB framework, researchers explain that individuals with higher perceived social acceptance and stronger SE are more likely to engage in certain behaviors in reality (88), a viewpoint our research also supports. Furthermore, we found a positive link between Social Norms (SN) and SE, where an increase in SN is accompanied by a rise in SE, similar to our findings, anothers also showed thereby positively affecting the intention to participate in health behaviors (89). In health behavior promotion, the external environment's impact on SE could either facilitate or hinder self-care behaviors (90).

This study also discusses the role of SE in TPB, which is consistent with the conclusion of many researchers that SE better explains individual behavior in TPB (85). For example, in studies on voluntary blood donation behavior, experienced blood donors with higher SE were more susceptible to the influence of their participation behavior (86). In a study of poor eating habits in obese individuals, those with lower SE were less able to control their weight, making successful weight loss more challenging (26). Overall, within the framework of the TPB, the researchers explained that individuals with higher perceived social acceptance and more robust SE are more likely to perform certain behaviors in reality (88), and our research supports this view. In addition, SN and SE influence each other. When SN increases, SE will also increase. SE can increase an individual's subjective commitment to perform a specific health behavior and fulfill others' expectations, thus positively affecting the intention to participate (89).

In addition, there is a positive correlation between PBC and PI. However, the strength of this relationship is weaker compared to SN and SE, which is consistent with previous studies in the literature (91, 92). Our findings support this notion. When SE and PBC coexist, SE can serve as a better measure (93). In 2020, Ajzen proposed after further research on TPB that both refer to people's belief in their ability to perform a given behavior. However, operationally, PBC and SE are often assessed different ways (94). This also confirms previous research results.

Interestingly, a significant difference found in this study compared to previous studies is that AT's impact is smaller than other influencing factors. Our survey on AT is consistent with a small number of prior investigations (31, 54). There may be several reasons for this result. First, the retired group has a low level of education and limited knowledge of health examinations, resulting in distrust and disparity

TABLE 4 Discriminant validity test.

	AT	SN	PBC	SE	PI	PB
AT	**0.833**					
SN	0.292	**0.792**				
PBC	0.389	0.339	**0.843**			
SE	0.335	0.319	0.331	**0.803**		
PI	0.192	0.248	0.214	0.261	**0.787**	
PB	0.387	0.493	0.425	0.507	0.439	**0.800**

AT, Attitude; SN, Subject norm; PBC, Perceived behavioral control; SE, Self-efficacy; PI, Participate intention; PB, Participate behavior; Figures on the diagonal line (in bold) are the square root of the average variance extracted (AVE). Off-diagonal figures show inter-construct correlations.

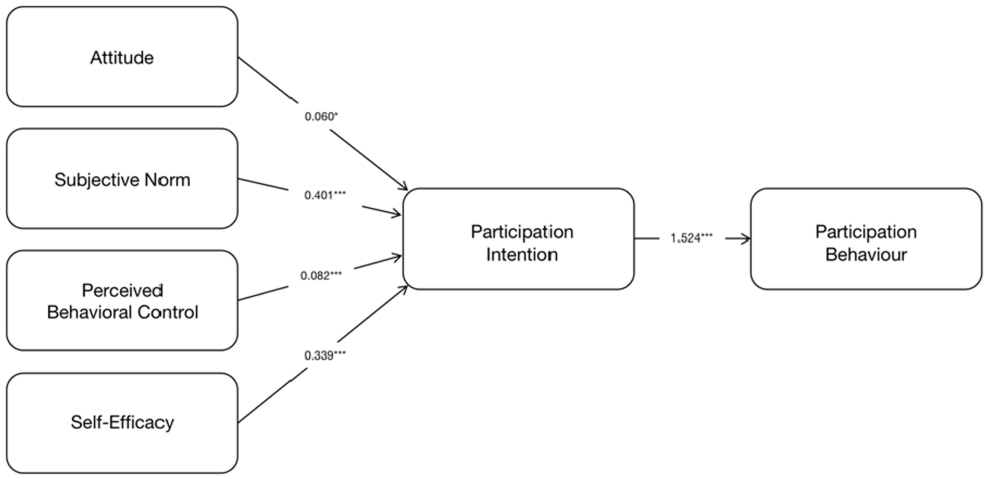

FIGURE 2
Standardized structural estimates and hypotheses tests, *$p < 0.05$, ***$p < 0.001$.

TABLE 5 Hypothesis testing and path size significance.

Hypothesis/Path	Estimate	S.E.	C.R.	*t* value	Results
Hypothesis 1. AT→PI	0.060*	0.023	2.576	0.981	Supported
Hypothesis 2. SN→PI	0.401***	0.079	5.054	2.513	Supported
Hypothesis 3. PBC→PI	0.082***	0.024	3.357	1.385	Supported
Hypothesis 4. SE→PI	0.339***	0.065	5.240	2.751	Supported
Hypothesis 5. PI→PB	1.524***	0.287	5.309	8.591	Supported

AT, Attitude; SN, Subject norm; PBC, Perceived behavioral control; SE, Self-efficacy; PI, Participate intention; and PB, Participate behavior; *$p < 0.05$, ***$p < 0.001$.

in health. This is consistent with the research of Zheng (95) and Guo (96). When patients have a low disease background, health information avoidance will make people face the disease or take preventive measures. Based on these factors, individuals may exhibit avoidance attitudes (AT) toward health examinations, which does not positively affect their willingness to participate (PI). Secondly, another possible reason for this result may be the existence of a neutral attitude (97, 98). Recent research (99) confirms that an apathetic attitude is negatively related to behavior. In this study, retirees showed no apparent positive or negative attitudes toward health screenings, defined as neutral attitudes. Another possible explanation for speculation is that attitudes toward current health research differ due to different target types (health protection and health risks) (40). Attitudes show great predictive power when directed toward high-reward health behaviors—health-risk behaviors, such as smoking or alcohol abuse. Therefore, the impact of AT on PI is relatively small in this case. Since this study is an empirical study, local retirees may be neutral in their attitudes toward whether to participate in health screening, and there may be other unmeasured antecedent variables that impact AT results. The measurement of AT and its role in health screening PI warrants further study.

5.1.2 Predictive factors of health screening behavior

In this research, we also determined the influence coefficient of PI-PB, the final link of TPB, which further confirmed that TPB is suitable for studying voluntary behavior and its applicability in health behavior. Accumulated evidence shows that intention is the most crucial factor in the theory of planned behavior. Best predictor. PI effectively promotes the generation of PB in health behaviors, which is consistent with previous findings in the intention-behavior relationship that reasonable intentions may provide better behavior prediction (100–102). This provides strong evidence for the decisive impact of PI on PB. In our study, the effects of AT, SN, PBC, and SE on participation intention were all valid, and the impact of PI on retiree health checkup PB was not inconsistent with previous studies. This provides strong evidence for the decisive impact of PI on PB. Retirees have a strong willingness to participate in health screening. In previous studies (67), people were restricted from participating in various health examinations, which may be why people are not enthusiastic about participating in health examinations. Because of intention-behavior congruence, this also means that people are less likely to engage in healthy behaviors when intentions are not strong.

This study aims to identify the factors that motivate Chinese retirees to participate in health screenings and how they influence their participation intentions by incorporating Self-Efficacy (SE) into the Theory of Planned Behavior (TPB). A distinctive aspect of this research is the addition of new variables to overcome the TPB model's limitations in explanatory power. This approach coincides with Ranjbaran's study, where SE not only enhances the TPB's explanatory power for health participation behavior but also provides a unique perspective for discussions on health promotion and public health (103). Enhanced the explanatory power of the model in health participation behavior. This study focuses on exploring the individual participation behavioral intentions of retired people through the perspective of TPB. This unique perspective contributes to discussing health promotion, public health, and active aging. Third, to the best of the researchers' knowledge, this study is one of the few empirical studies on retiree health screening behavior and intention to participate. The results of SEM show that all hypotheses in the extended TPB model are significantly supported, and the final data are consistent with the theoretical predictions. This makes this study significant and further proves TPB's predictive utility. Judging from the results of this study, it is valuable for us to extend the TPB model, which will validate its effectiveness in health promotion research. To explore the effective expansion of the TPB expansion model in health participation behavior in public health and healthcare.

5.2 Implications

5.2.1 Theoretical implications

This study provides theoretical and practical research. The theoretical contributions derived from this study are, first, an in-depth exploration of the particularities of the retired group, considering that their life situations, personal needs, and experiences are significantly different from those of other age groups. Therefore, their socio-psychological factors, including AT, SN, PBC, and SE also show different characteristics. Notably, unlike previous research, we found that PBC did not predict behavioral intentions among retired people as strongly as expected. We also observed differences in people's AT for health checks in different social backgrounds. SN of retired groups and SE of new entrants are significant predictors. Therefore, an in-depth understanding of these factors is crucial to improving the intention of retired people to participate in health checks. Secondly, the study introduced self-efficacy and incorporated it into the TPB model, which can better adapt to the needs of this retired group. The results suggest that targeting participation intentions among retired people may require particular emphasis on subjective norms and self-efficacy rather than just changing attitudes. This theoretical expansion helps to understand better the decision-making process and behavioral intentions of retired people and provides more comprehensive evidence for health promotion and intervention. Finally, by integrating

social psychology (SE) and decision-making theory (TPB), we provide a broader perspective on understanding the decision-making process for health behaviors. This integration fills the theoretical gap between the two and helps better meet retired groups' needs in health behavior intervention. By focusing on this specific group, we help fill the knowledge gap about the health behaviors of retired people. Therefore, it is significant to study the relationship between participation intentions and participation behaviors in retired people. With these in mind, we recommend incorporating research samples into health management studies of older adults to understand better and address their needs.

5.2.2 Practical implications

Practically, research on retirees' health checkup willingness provides valuable suggestions for improving the follow-up health checkup service process. First, our findings highlight the importance of subjective norms and self-efficacy. Self-efficacy is vital among people aged 25–65, and personal perceptions are highest during this period. In contrast, after age 65, self-efficacy will weaken with subjective perception, and mental and physical health will decline, damaging personal autonomy. However, family support and social support will significantly improve this situation. Healthy psychological and social factors determine the health outcomes of retired people, and social support has profound health benefits for them. As a social and psychological pressure, retirement has a huge impact on retired people. This can improve SE through strategies such as planning a series of health screening.

On the other hand, both interpersonal influence and external influence have a positive impact on subjective norms. Among them, social networks (i.e., social support) under the Internet are the best embodiment of external power. In China, most retirees always stay on their mobile devices, and their daily lives must be separated from the mobile Internet. Social software allows people to communicate more frequently, quickly, and effectively and is more susceptible to their influence. The Internet's rapid development has reduced the lag in obtaining external information. They can promptly obtain information that is difficult to distinguish between true and false, feedback from mass media, recommendations from merchants, and even advertisements based on geographical location, which make them more susceptible to external influence. Health service operators can comprehensively promote the benefits of health examinations and the importance of health through the Internet and can also apply them to improve lifestyles after health examinations. For example, subjective norms can be reinforced through regular reminders from family, friends, doctors, or health management software, as well as relevant news notifications from government policies and media agencies. These measures will help improve customer satisfaction with health examination services, improve the quality of health examination services, and help formulate relevant policies and plans for health checks services. Since 2018, Chinese physical examination institutions have been increasing year by year and launching physical examination packages for different types of groups. A complete health examination service process can improve customers' overall health examination experience and willingness to conduct regular health checks.

5.2.3 Policy implications

Finally, this study provides some policy implications. This study discusses factors that significantly influence the participation experience of the retired population. It is worth pointing out that regular health checks have always been a healthy lifestyle recommended by the government, especially for controlling blood pressure and blood sugar, which is crucial for preventing most chronic diseases. The government encourages retired people to use these resources to actively participate in health check-ups by providing free health checks opportunities and publishing and disseminating relevant information. In recent years, innovative medical care and healthy aging have become increasingly popular in China, and more and more hospitals and medical institutions have continued to upgrade and improve the quality of medical services. Policies such as smart medical care and healthy aging are continuously optimized and upgraded in this process. Future policymakers can refer to these related influencing factors when discussing future policies or regulations on intelligent healthcare and healthy aging. In addition, as healthy aging and smart healthcare continue to develop, and more and more institutions invest in them, health examination policies will face many challenges, such as addressing ethical issues, privacy concerns, and individual rights issues when formulating examination activities. Our study takes a first step toward addressing these challenges by identifying specific influencing factors that may contribute to these problems. These influencing factors provide us with valuable entry points to address these challenges.

5.3 Limitations and future directions

This research identified three limitations that should be considered when interpreting the results. Firstly, due to the limitation of sample size, our research can only represent some retired individuals, which may affect the generalizability of the findings. Additionally, our model may not include other potential influencing factors, such as the quality of health examination services and economic factors. Including these factors could yield different results and provide a more comprehensive understanding of the factors influencing retired individuals' intention to participate in health examinations. Lastly, this research is based on a cross-sectional survey with a single dataset, which limits the ability to establish causal relationships. The research did not consider the time frame (e.g., "in the past," "before retirement," or "soon to retire") for investigating the mindset changes before and after retirement. It would be valuable for future research to explore longitudinal changes in the attitudes of retired individuals toward health examinations if the survey data allow for such analysis.

6 Conclusion

This study delves into the relationship between retirees' intentions to participate in health screenings and their actual behavior by extending the TPB and incorporating SE. The findings reveal a significant positive impact of SN and SE on retirees' intentions to participate in health screenings while also confirming the mediating role of intention between AT, SN, PBC, and SE. These results are consistent with previous TPB-based studies both domestically and internationally, further emphasizing the importance of considering SE in health behavior research. It further proves the predictive utility of TPB and its extended model in health promotion research, offering a new perspective on understanding retirees' health screening behaviors,

especially in assessing how social support and personal beliefs influence health behavior intentions. Additionally, by including SE as a component of the TPB model, this study enhances the model's explanatory power in explaining health participation behavior, providing a unique perspective for discussions on health promotion, public health, and active aging and laying a theoretical foundation for future health promotion strategies.

On a practical level, this study offers valuable insights for health screening service companies and policymakers. It highlights the need to pay special attention to enhancing retirees' sense of social norms and SE when designing health screening services and related policies to promote their active participation. Moreover, the study's findings support the idea that future policies should focus more on retirees' health screening experiences to increase their willingness and frequency of participation in health screenings.

Despite its theoretical and practical contributions, this study has limitations, such as sample representativeness and consideration of potential influencing factors. Therefore, future research needs to explore other factors that may influence retirees' health screening behaviors further and how different interventions can effectively increase their willingness to participate.

This study underscores the importance of understanding and enhancing social norms and SE in promoting retirees' participation in health screenings. By designing interventions targeting these factors, we can more effectively promote health management among retirees, thereby improving public health standards and the quality of life for the older adult.

Data availability statement

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

Ethics statement

This study complied with the recommendations of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of Shizong County, Yunnan Province, ethics code/number: YNSZ-IRB-020-20230524.

Author contributions

JX: Conceptualization, Formal analysis, Methodology, Software, Supervision, Validation, Writing – original draft. YP: Supervision, Writing – review & editing. QL: Data curation, Investigation, Writing – original draft.

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Conflict of interest

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

Publisher's note

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Profiles in neglect of older adult care workers in a long-term care facility: a latent profile analysis

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Background: Neglect is a common form of abuse, and long-term care facilities record higher incidences of this abuse. Given that older adult care workers are the main workforce in these facilities, their neglectful behavior requires public health attention. Internal individual characteristics can lead to older adult abuse, and managing workers who abuse older adults may require various methods. This study aimed to identify the profiles of neglect among older adult care workers in long-term care facilities and explore the influencing factors of neglect.

Methods: In this cross-sectional study, a convenience sample of older adult care workers from 15 long-term care facilities in Shandong Province (N = 421) completed a questionnaire on the characteristics associated with neglect. Latent profile analysis was used to identify distinct neglect profiles and promote the understanding of individual characteristics associated with varying levels of neglect. One-way analysis of variance and multivariate logistic regression analyses were used to examine the population characteristic differences.

Results: Older adult care workers exhibited three neglect profiles, namely, the "low-risk group," "medium-risk group," and "high-risk group." Males, participants with no employment qualification certificate, and those who did not attend regular training represented the majority of those in the "high-risk group." Participants with a monthly income of more than ¥ 4,000 and nursing 1–2 older adults simultaneously represented the majority of those in the "low-risk group."

Conclusion: Long-term care facility administrators should tailor interventions to individual care worker profiles to reduce neglect behaviors and improve care levels.

KEYWORDS

older adult care workers, older adult abuse, older adult mistreatment, latent profiles analysis, long-term care facilities (LTCFs)

Introduction

Population aging is a major developing global issue, including in China. The increase in aged population has introduced a significant burden on family care, which plays an important role in caring for older adults. At the same time, the transformation of the family structure, caused by the implementation of the family planning policy, development of the social economy, reduced fertility and mortality rates, and extended average life expectancy of the population, is bound to have a huge impact on the traditional home care model (1). China's family structure is gradually showing a trend of miniaturization and aging, and the

proportion of "421" families, which means a couple needs to support four older adults and raise one child, is increasing yearly (2). Therefore, the number of family members available to take care of older adults is relatively reduced, which will eventually weaken the home care function and increase the burden and pressure on younger adults. Consequently, older adults gradually have reduced access to care resources provided by their families. It may be advantageous to focus on institutional care rather than on home care, and institutional care may become a main option for older adults (3).

The care for older adults in the majority of the institutions is provided by care workers. However, the high proportion of older adults and the shortage of care workers has increased the complexity of older adult care. The lack of nursing skills and improper attitude or behavior could lead to older adult abuse in the provision of older adult care (4). A 2020 meta-analysis showed that the incidence of older adult abuse in China was as high as 20.29% (5) while another study showed that a quarter of frail older adults were at risk of abuse and neglect, but only a small proportion could be identified (6). It is highly possible that such abuse is mostly ignored due to the lack of awareness of abuse among care workers. This may lead to serious consequences such as decreased quality of life, adverse health outcomes, and increased morbidity among older adults. The World Health Organization defines older adult abuse as "a single or repeated act or lack of appropriate action, occurring within any relationship where there is an expectation of trust, which causes harm or distress to an older person" (7). The five types of older adult abuse are, namely, physical abuse, mental abuse, economic abuse, sexual abuse, and neglect, with neglect being the most prevalent. Neglect refers to a relationship where an individual intentionally or unintentionally refuses to provide care to an older adult, cannot provide the older adult with the needed resources or services, or fails to protect the older adult from unnecessary harm. It can be divided into four types, namely, physical, psychological, economic, and medical neglect (8). In long-term care facilities, physical neglect is defined as the refusal or failure to provide basic goods or services to the older adult, including failure to provide adequate food, water, and clothing; aids; and safety protection. Physical neglect may lead to malnutrition, fecal impaction, stress ulcers, poor personal hygiene, or failure to seek medical care in older adults. Psychological neglect refers to the failure to ensure that older adults maintain normal social interactions, such as failing to provide any form of companionship for the older adult. Psychological neglect in older adults may lead to withdrawal, depression or anxiety, and ambivalence toward care workers. Economic neglect is the failure to utilize available funds and resources to maintain or restore the health of older adults, which is the case in situations where older adults are unaware of their financial situation or the sudden transfer of property to family members. Medical neglect refers to situations where older adults have unmet medical needs resulting from failure to take medications on time or attend medical check-ups. Studies have highlighted that the incidence of neglect in long-term care facilities is higher, ranging from 20% to 30% (9). Neglect may adversely affect a person's physical and mental health, causing temporary or long-term physical problems, anxiety, stress, sleep difficulties, and even suicidal ideations, and it may increase the risk of hospitalization and premature death (10). Therefore, neglect of older adults in long-term care facilities deserves public health attention.

Older adult care workers play a very important part in routine care for older adults, so they are the main source of neglect. The trait theory suggests that individual personality traits have a significant impact on their work behavior, and different behavioral tendencies trigger different behaviors. It is important to consider the personal characteristics and professional skills of older adult care workers, as they play a crucial role in older adult care and neglect. Previous research has focused on investigating the relationship between neglect and various factors such as work stress (11), social support (12), care setting (13), and professional attitudes (14). However, these studies have primarily examined correlations between variables, often using comprehensive scores to represent the overall situation without delving into individual differences in neglect.

Latent profile analysis (LPA) is a human-centered algorithm that can categorize responses from individuals with similar characteristics in different items and different categories with significant characteristics, ensuring the greatest difference between categories and the smallest difference within categories (15). In LPA, observed variable covariances are decomposed to reveal relationships among people instead of discovering associations among variables (16). It can provide an opportunity to uncover subgroups that have common neglect profiles and their correlates but with important distinctions. Therefore, we investigated whether older adult care workers can be divided into distinct subtypes based on their traits and behaviors using LPA, which can both provide a focused intervention for care workers to lessen the impact of neglect and help administrators of long-term care facilities in screening for appropriate older adult care workers during recruitment.

Methods

Sample and measures

Shandong University's Institutional Review Board approved the study protocol. In this study, the post-stratified convenience sampling method was used. Shandong Province was divided into five layers according to the administrative region, and one city was randomly selected from each layer. Among the registered long-term care facilities in each city, three facilities were conveniently sampled according to the different forms of operation (public operation, state-found-private-run, and private). Therefore, 15 institutions were selected from the total number of 962 institutions with complete medical and nursing certificates in Shandong Province (Data from Xinhua News Agency Jinan, 29 July 2023).

Data were collected through an online and offline questionnaire survey. The principal person in charge of each long-term care facility gave their consent before the survey was conducted. We selected the respondents based on the inclusion and exclusion criteria, and after explaining the research purpose, significance, and fulfilling requirements, we assured every respondent that the completed data would be kept anonymous and confidential. We obtained written informed consent from the participants. No privacy information was involved during the data collection

process, and the ethical principles of voluntary participation, anonymity, and confidentiality were guaranteed. To avoid repeated filling of questionnaires, the same facility was surveyed using only one form of questionnaire (online or offline). Each question in the online questionnaire was set as a mandatory field and the offline questionnaire was collected face-to-face by the researcher to ensure that no questions were missed during the completion of the questionnaire. For those with low educational levels or dyslexia and who could not fill the questionnaires independently, the questionnaire items were read out to them and their responses were documented through face-to-face means. The care workers who could not understand the content of the questionnaire were excluded due to the possibility of serious personal subjectivity and bias. Among the 15 long-term care facilities, only two facilities opted for the online questionnaire due to the time conflict between the research schedule and the vacation of nursing staff in the institutions. The response rate of those who filled out the online questionnaire was 93.75%, and four questionnaires were eliminated because they were not carefully filled. The response rate of those who filled out the offline questionnaire was as high as 98.63%, and five questionnaires were not completed due to reluctance to fill the questionnaire and due to other reasons. A total of nine questionnaire responses were excluded. Two investigators independently reviewed the data.

The inclusion criteria were (1) older adult care workers (those who provided care to older adults aged 60 years and above); (2) care workers aged 18 years and above; (3) care workers who have worked in nursing institutions for 3 months and longer (17); and (4) care workers who provided informed consent to participate in the study. The exclusion criteria were older adult care workers (1) who could not understand the questionnaire after explanation and (2) who were on leave and who had left work for training and further studies.

The Elder Neglect Scale for Geriatric Nursing Assistants (ENS for GNA)

The Elder Neglect Scale for Geriatric Nursing Assistants (ENS for GNA) (17) assessed older adult neglect. The scale includes 4 dimensions and 17 items: physical neglect (5 items), psychological neglect (4 items), economic neglect (3 items), and medical neglect (5 items). Each item was scored on a Likert scoring scale of 0–5, with total scores ranging from 0 to 85; higher scores indicate the lower risk of neglecting older adults. The rationality of the scale among the nursing population was verified. The scale has good credit validity, with a Cronbach's α coefficient of 0.877, a test-retest reliability of 0.944, and a content validity of 0.984. Zhang et al. (18) tested the reliability and validity of the scale in a study of older adult care workers, and the Cronbach's α coefficient was above 0.80.

Chinese big five personality inventory brief version

The Chinese Big Five Personality Inventory brief version (19) contains 5 dimensions, each containing 8 items for a total of 40 items: neural, rigor, agreeableness, extraversion, and openness. The responses were graded using a 6-level Likert scoring scale, ranging from 1 to 6 points. The total score for each dimension was summed up, and it ranged from 8 to 48. The higher the dimension score, the more obvious the personality tendency. The Cronbach's α coefficient of all the five dimensions was above 0.75, with a minimum of 0.76 (agreeableness), a maximum of 0.81 (neuroticism), and an average of 0.79. We tested the reliability and validity of the scale in this study, and the Cronbach's α coefficient was 0.891.

Demographic information

The research team designed the form based on the relevant previous literature to obtain demographic information. The following data were obtained: age, sex, marital status, education level, monthly income, employment qualification certificate, nature of the facility, regular training attendance, years of experience in the provision of older adult care, and number of older adults who are nursed simultaneously.

Statistical analysis

We used LPA to identify traits of neglect in older adult care workers. Despite the possible arbitrariness of LPA in determining the number of class members due to its semi-subjective properties, its misclassification rate is relatively low, and it can produce more reasonable results compared with those of other classification approaches (20). We used Mplus v8.3 to identify the number of distinct care worker subtypes, the relative size of each subtype, and the distribution of characteristics within each subtype (15). Using stepwise addition, k+1 classes were added sequentially until the optimal solution for the data was obtained. The Akaike information criterion (AIC) is a standard for measuring the goodness of fit of statistical models. When choosing the best model from a set of models, the model with the smallest AIC is usually selected. The Bayesian information criterion (BIC) is similar to the AIC and is used for model selection. The BIC considers the number of samples. When the sample size is too large, the BIC can effectively prevent the model complexity caused by excessive model accuracy. The sample-size adjusted BIC (aBIC) is also used to assess the model fitting effect. Entropy is a measure from zero to one of how well individuals are assigned to latent classes (class differentiation). Entropy evaluates the classification quality of a model, with a value closer to 1 indicating a more accurate classification. The Lo–Mendell–Rubin likelihood ratio test and the bootstrap likelihood ratio test are used to examine the fit differences across different category models, demonstrating that when statistically significant, the k-category model beats the k-1 category model. When the category model for evaluating index tendency is inconsistent, the optimal model is chosen by completely measuring the outcomes of each index, considering their clinical relevance, and integrating the principles of interpretability and brevity.

After determining the best latent profile model and defining the classifications, statistical analysis was performed using SPSS25.0. Normally distributed continuous data were expressed as mean

TABLE 1 The sample characteristics of older adult care workers ($N = 421$).

Item	Classification	Number/score	Percentage (%)
Sex	Male	84	19.95
	Female	337	80.05
Age	20∼40	189	44.89
	41∼60	221	52.50
	>60	11	2.61
Marital status	Unmarried	72	17.10
	Married	317	75.30
	Other	32	7.60
Years of old care work	<Half a year	20	4.75
	Half a year ∼1 year	72	17.10
	1 year∼3 years	141	33.49
	3 year∼5 years	69	16.39
	≥5 years	119	28.27
Education level	Illiteracy	21	4.99
	Elementary education	123	29.22
	Secondary education	269	63.89
	Higher education	8	1.90
Monthly income	<2,000 yuan	19	4.51
	2,000∼3,000 yuan	48	11.40
	3,001∼4,000 yuan	136	32.30
	4,001∼5,000 yuan	156	37.06
	>5,000 yuan	62	14.73
Nature of the facility	Public operation	247	58.67
	Private	88	20.90
	State-found-private-run	86	20.43
Have the employment qualification certificate	Yes	344	81.71
	No	77	18.29
Attend the training regularly	Yes	293	69.60
	No	128	30.40
Nursing number of older adults simultaneously	1∼2	143	33.97
	3∼4	129	30.64
	>4	149	35.39

± standard deviation, and categorical data were expressed as frequency and percentage (%). The Chi-square test or one-way analysis of variance was used to assess the correlation of demographic information and personality with different characteristics of neglect. Statistically significant variables in the univariate analysis were further included in a stepwise multivariate logistic regression analysis. The parallelism test ($x^2 = 40.096$, $P = 0.003$) was significant, thus multivariate disordered logistic regression analysis was performed to evaluate the influencing factors of different latent categories of neglect characteristics. Odds ratios (ORs) and corresponding 95% confidence intervals (95% CIs) were calculated to assess the results of the regression analysis. The test level was $\alpha = 0.05$, and $P < 0.05$ was considered statistically significant.

Results

Sample characteristics

In this study, 430 older adult care workers were selected from 15 long-term care facilities in Shandong Province from June to September 2022. Nine invalid questionnaires were excluded, and the final sample was 421. Older adult care workers were mainly young and middle-aged adults and mostly women (80.05%). Most of them were married (75.30%), 344 had the employment qualification certificate (81.71%), 293 attended training regularly (69.6%), and one-third provided care for more than four older adults simultaneously (35.34%). The monthly income of the participants was ¥3,001–5,000, accounting for 69.36% of the participants. The nature of long-term care facilities was mainly a public mode of operation, accounting for 58.67% of the included facilities. Additional information is presented in Table 1.

Latent profile analysis

The number of latent categories was gradually increased from one, and five latent category models were established. Table 2 displays the fitting indicators of the latent profile model of neglect among older adult care workers. The results show that AIC, BIC, and aBIC decreased with the number of latent categories, but the decline rate began to slow down when the number of latent categories was three. Entropy was maximum when the three categories were retained. Therefore, three-category models were developed as the optimal classification results of neglect among older adult care workers.

The scores for each dimension of neglect in different latent profile categories are shown in Table 3. The subtypes of older adult care workers were assigned descriptive labels based on their characteristics/behaviors. Class 1: care workers in this group had the lowest score in each dimension (i.e., the degree of neglect) and a high risk of neglect of older adult care; they were labeled as the "high-risk group" (13.06%). Class 2: care workers in this group had their scores for each dimension between those of workers classified as C1 and C3 and were considered the "medium-risk group" (33.50%). Class 3: care workers in this group had the highest scores in all the dimensions (i.e., degree of neglect), and the older adults they cared for were the least overlooked; they were labeled as the "low-risk group" (53.44%).

TABLE 2 The latent profile fitting indicator of neglect among older adult care workers ($N = 421$).

Model	AIC	BIC	aBIC	Entropy	LMR (P)	BLRT (P)	Class probability
1	8,705.067	8,737.408	8,712.022	—	—	—	100
2	8,068.494	8,121.048	8,079.795	0.910	0.0000	0.0000	0.68/0.32
3	7,953.258	8,026.025	7,968.905	0.931	0.0009	0.0000	0.53/0.34/0.13
4	7,877.995	7,970.976	7,897.989	0.901	0.0003	0.0000	0.51/0.19/0.19/0.11
5	7,822.934	7,936.128	7,847.275	0.899	0.0054	0.0000	0.44/0.19/0.18/0.11/0.08

TABLE 3 A comparison of scores for each dimension of neglect in different latent profile categories ($N = 421$).

Category	Number	Physical neglect	Psychological neglect	Economic neglect	Medical neglect
Low-risk group	225	24.15 ± 1.02	17.67 ± 2.36	12.27 ± 2.49	23.60 ± 2.07
Medium-risk group	141	19.59 ± 1.15	15.73 ± 2.38	10.41 ± 2.54	19.72 ± 2.75
High-risk group	55	14.69 ± 1.71	12.42 ± 2.89	8.24 ± 2.14	16.55 ± 2.30
F value		344.498	108.740	67.762	222.792
P-value		<0.001	<0.001	<0.001	<0.001

Univariate analysis results

Univariate analysis was performed based on the LPA findings regarding the neglect behavior of older adult care workers. The results showed that factors such as sex; age; monthly income; nature of the facility; having an employment qualification certificate; attending training regularly; nursing a number of older adults simultaneously; and rigor, agreeableness, and extraversion personalities were statistically significantly different among the risk groups ($P < 0.05$; Table 4). However, no statistically significant difference in marital status and educational level was observed among the groups ($P > 0.05$). The high-risk group included the proportion of workers who were males, aged 20–40 years, with older adult care experience of <1 year, who were working in a private facility, with no employment qualification certificate, and who did not attend regular training was higher than that of those in the other two groups. The low-risk group included the proportion of workers who were female, with older adult care experience of more than 5 years, with a monthly income of more than ¥5,000, who were working in a public operation facility, with an employment qualification certificate, who regularly attended older adult care training, and who provided care for less number of older adults simultaneously was higher than that of those in the other two groups.

Multivariate logistic regression analysis results

Variables with statistical significance in the univariate analysis were included as independent variables and covariates, and three potential categories, namely, high-, medium-, and low-risk groups were analyzed as dependent variables. The results showed that males in the high-risk group had a 3.293 times higher risk of neglect than that observed in the low-risk group (OR = 3.293, $P = 0.006$). Older adult care workers with low monthly income in the medium-risk group had a 3.034 times higher risk of neglect than that observed in the low-risk group (OR = 3.034, $P = 0.002$). Older adult care workers with an employment qualification certificate (OR = 0.361, $P = 0.018$), who attend training regularly (OR = 0.572, $P = 0.035$), and who nurse <4 older adults simultaneously (OR = 0.474, $P = 0.012$) were less likely to exhibit neglect behaviors, as shown in Table 5.

Discussion

Overall findings

This study identified three potential categories of older adult care workers, namely, high-, medium-, and low-risk groups of neglect, using LPA. Nearly half of the older adult care workers were at high or medium risk of exhibiting neglect behaviors. Additionally, this study considered the traits and motivating elements of these groups, which is anticipated to aid the management of long-term care facilities in identifying caregivers who are at high risk of exhibiting neglect behaviors and in developing intervention plans.

The results showed that the incidence of neglect of care was lower in this study than in the study by Zhang et al. (18). Although both studies are on older adult care workers in long-term care facilities, more than half of the respondents in Zhang et al.'s study worked in private facilities. The funds and resources available for private facilities are less abundant than those of public-operated facilities. These private facilities impose a heavy burden on care workers, have poor professional nursing staff, and have a weak ability to provide high-level nursing service for older adults, which can likely to lead to a higher neglect rate. The following were identified as the causes of the lower rate of neglect in this study: (1) long-term care facilities focus on the skill training and service quality of older adult care workers to attract more older

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TABLE 4 Univariate analysis of neglect in different latent profile categories.

Item	Classification	Latent profile categories			x^2/F	*P* value
		Low-risk group (225)	Medium-risk group (141)	High-risk group (55)		
Sex	Male	31 (13.78)	26 (18.44)	27 (49.09)	$x^2 = 34.811$	<0.001
	Female	194 (86.22)	115 (81.56)	28 (50.91)		
Age	20∼40	93 (41.33)	60 (42.55)	36 (65.45)	$x^2 = 15.605$	0.048
	41∼60	125 (55.56)	78 (55.32)	18 (32.73)		
	>60	7 (3.11)	3 (2.13)	1 (1.82)		
Marital status	Unmarried	39 (17.33)	22 (15.60)	11 (20.00)	$x^2 = 3.132$	0.536
	Married	165 (73.33)	112 (79.43)	40 (72.73)		
	Other	21 (9.34)	7 (4.97)	4 (7.27)		
Years of old care work	< half a year	11 (4.89)	4 (2.84)	5 (9.09)	$x^2 = 16.512$	0.036
	Half a year ∼1 year	28 (12.44)	27 (19.15)	17 (30.91)		
	1 year∼3 years	77 (34.22)	49 (34.75)	15 (27.27)		
	3 year∼5 years	40 (17.78)	24 (17.02)	5 (9.09)		
	≥5 years	69 (30.67)	37 (26.24)	13 (23.64)		
Education level	Illiteracy	11 (4.89)	8 (5.67)	2 (3.64)	$x^2 = 5.292$	0.726
	Elementary education	70 (31.11)	41 (29.08)	12 (21.82)		
	Secondary education	139 (61.78)	91 (64.54)	39 (70.90)		
	Higher education	5 (2.22)	1 (0.71)	2 (3.64)		
Monthly income	<2,000 yuan	8 (3.56)	8 (5.67)	3 (5.45)	$x^2 = 22.756$	0.004
	2,000∼3,000 yuan	16 (7.11)	20 (14.18)	12 (21.82)		
	3,001∼4,000 yuan	69 (30.67)	44 (31.21)	23 (41.82)		
	4,001∼5,000 yuan	93 (41.33)	54 (38.30)	9 (27.85)		
	>5,000 yuan	39 (17.33)	15 (10.64)	8 (15.36)		
Nature of the facility	Public operation	153 (68.00)	72 (51.06)	22 (40.00)	$x^2 = 21.429$	<0.001
	Private	32 (14.22)	37 (26.24)	19 (34.55)		
	State-found-private-run	40 (17.78)	32 (22.70)	14 (25.45)		
Have the employment qualification certificate	Yes	197 (87.56)	118 (83.69)	29 (52.73)	$x^2 = 36.428$	<0.001
	No	28 (12.44)	23 (16.31)	26 (47.27)		
Attend the training regularly	Yes	178 (79.11)	88 (62.41)	27 (49.09)	$x^2 = 23.996$	<0.001
	No	47 (20.89)	53 (37.59)	28 (50.90)		
Nursing number of older adults simultaneously	1∼2	92 (40.89)	44 (31.21)	7 (12.73)	$x^2 = 25.734$	<0.001
	3∼4	71 (31.56)	33 (23.40)	25 (45.45)		
	>4	62 (27.55)	64 (45.39)	23 (41.82)		
Big five personality	Neural	22.56 ± 10.53	22.51 ± 10.47	22.47 ± 10.53	$F = 2.116$	0.122
	Rigor	36.61 ± 7.49	36.61 ± 7.47	36.64 ± 7.51	$F = 13.417$	<0.001
	Agreeableness	32.39 ± 6.04	32.36 ± 5.99	32.43 ± 5.99	$F = 3.792$	0.023
	Extraversion	33.64 ± 8.11	33.62 ± 8.10	33.59 ± 8.16	$F = 4.630$	0.010
	Openness	30.53 ± 6.96	30.49 ± 6.94	30.53 ± 6.96	$F = 1.925$	0.147

adults; this ensures that the older adults receive improved care; (2) the majority of older adult care workers who completed the questionnaire provided care to only few older adults who were bedridden, indicating that the older adults had sufficient self-care abilities and did not require as much assistance from older adult care workers (21). Although the possibility of neglect was low in this

TABLE 5 The results of multivariate logistic regression analysis of neglect potential profiles.

Item	Medium-risk group vs. Low-risk group				High-risk group vs. Low-risk group			
	β	*OR* (95%*CI*)	*Wald* x^2	*P*	*β*	*OR* (95%*CI*)	*Wald* x^2	*P*
Sex	0.100	1.106 (0.572∼2.136)	0.089	0.765	1.192	3.293 (1.405∼7.721)	7.519	0.006
Monthly income	1.138	3.121 (1.160∼8.397)	5.080	0.024	0.424	1.527 (0.394∼5.916)	0.376	0.540
Have the employment qualification certificate	−0.048	0.953 (0.478∼1.899)	0.019	0.890	−1.02	0.361 (0.155∼0.839)	5.598	0.018
Attend the training regularly	−0.558	0.572 (0.341∼0.961)	4.450	0.035	−0.461	0.631 (0.292∼1.361)	1.381	0.240
Nursing number of older adults simultaneously	−0.746	0.474 (0.264∼0.851)	6.265	0.012	−1.068	0.344 (0.117∼1.013)	3.749	0.053

study, it cannot be treated lightly in future studies. The training of older adult care workers should be strengthened to help them better understand the needs of older adults and reduce the occurrence of neglect.

Factors influencing neglect

The results of this study showed that the proportion of males was the largest in the high-risk group, which is consistent with previous studies (22). Alon et al.'s (23) research showed that three-quarters of the abusers were men. Arens et al. (24) also reported that men compared with women were more likely to neglect care. This finding may be related to the personalities. Men are generally not careful, while women are more meticulous, more thoughtful, and more patient with their work and lifestyle compared with that exhibited by men. Thus, women provide more comprehensive care to older adults and do not easily neglect the provision of care.

This study showed that not having an employment qualification certificate can easily lead to the neglect of care, which is consistent with Zhang et al.'s findings (18). Identifying neglect in daily life is difficult. Due to a lack of professionalism, older adult care workers without employment certificates may be unable to identify abuse or neglect events. Jiao et al.'s (25) research showed that older adult care workers with employment certificates scored higher in older adult care knowledge, interpersonal communication, psychological nursing, professional nursing knowledge, professional ethics, service etiquette, and emergency skills than the scores of non-certificated care workers, with statistical significance.

Older adult care workers who attend training regularly are less likely to neglect care. Those who failed to attend related training due to short rest time or low enthusiasm for related training did not improve their knowledge of older adult care at work. This results in inadequate knowledge and skills on older adult care and the inability to meet the needs of older adults (26), as well as increasing the probability of the occurrence of neglect.

In the medium-risk group, care workers with low monthly income were three times more likely to neglect care than those observed in the low-risk group, and the lower the income, the greater the probability of neglect. Liu et al. (27) found that 62.9% of older adult care workers had a low income, which was similar to the findings by Wan et al. (28). Their study showed that most older adult care institutions generally have problems such as the mismatch between salary level and labor intensity and poor treatment and welfare, and some institutions do not pay social insurance for older adult care workers (29). Income is the manifestation of a person's return for labor. In cases of the low-income level and high labor intensity, older adult care workers feel insecure. They assume that the job is extremely unstable to sustain passion over a long time, so they eventually neglect the provision of care to older adults.

The results showed that the low-risk group had care workers attending to fewer older adults simultaneously, which is similar to the findings of previous studies (30). In contrast, if the number of older adults is >4, care workers can only prioritize to meet the basic living needs of these older adults within their ability. These workers will ignore or cannot participate in psychological, rehabilitation, or medical projects (31).

The logistic regression results showed no statistically significant difference between personality characteristics and neglect. This is different from our previous assumption. Each kind of work has different requirements regarding work skills, psychological quality, and personality traits, and workers' own stable personality characteristics can provide an important reference for care facilities in the hiring and promotion of suitable candidates, matching individuals with specific work (32).

Implications for long-term care facilities

The results of this study showed that the proportion of the high-risk group was 13.06%, and attention should be paid to older adult care workers in this group. These workers had low

scores in all dimensions of neglect. As more older adults choose to remain in long-term care facilities, an imbalance between the number of care workers and allocated tasks may be observed. The reasons for psychological neglect among older adults may stem from a lack of professional skills and knowledge in psychological nursing, as well as the heavy daily work burden. Consequently, older adult care workers may inadvertently pay less attention to the psychological wellbeing of older adults. The cause of economic neglect may be due to the special nature of "money" and property, which are more private and sensitive issues for most older adults. If care workers manage older adults' money, some financial disputes could occur; therefore, they deliberately avoid involving themselves in the financial events of older adults (18). The cause of medical neglect may be due to the presence of some professional gap between medical staff and caregivers. For example, bedridden older adults do not feel convenient to express their feelings, and care workers can consequently ignore their poor health status (18). Therefore, care workers should pay more attention to the psychological condition of older adults, improve the attention given to the properties of older adults, timely observe and report the physical health of older adults, fundamentally reduce the occurrence of neglect, and improve the quality of life of older adults.

Care workers have a responsibility to ensure the safety of older adults who rely on them, protect them from abuse and neglect, and also ensure that older adults do not pose a risk to their families and any visitors they may have. The case described by Corbi clearly illustrates that neglecting the basic emotional needs of an older adult may lead to sexual abuse of others (33). Therefore, while taking care of older adults, more attention should be paid to their emotional needs. Long-term care facilities should establish mental health counselors to provide psychological counseling and emotional communication for older adults and strengthen the supervision of potential abusers.

This study found that males posed a high risk of neglect of care in long-term care facilities. This suggests that facilities should constantly improve the skills of male older adult care workers through lectures and attending education abroad to reduce the occurrence of neglect. Few studies have been performed on the effect of sex on neglect among older adult care workers in China, and further follow-up studies are needed to verify the effect of sex on neglect.

Identifying neglect in daily life is difficult. In some instances, neglect of care would have occurred, but the care workers were unaware of its occurrence, and in other instances, the care workers might not know what abuse or neglect is. The results of Corbi's survey also demonstrate that the level of awareness and perception of older adult abuse by healthcare professionals are still very poor, especially regarding the manner of reporting (34). The majority of nurses and the care assistants declared that they never had suspicions of abuse, and 50% of the nurses and 62.5% of the care assistants were unaware of standard reporting procedures. Meanwhile, nurses and physicians also lack knowledge about older adult abuse issues and the related laws. This phenomenon reflects the importance of the employment qualification certificate. In this study, although only a few care workers did not have employment qualification certificates, most of them did not pay attention to abuse and neglect as a problem in the provision of older adult care. Furthermore, the poor attitude of some practitioners toward older adults and the inability to relieve the work pressure lead to neglect. This suggests that older adult care workers should be actively encouraged to participate in the grade examination for obtaining the employment qualification certificate. In addition, the topic of older adults abuse and neglect education and specific assessment should be included in the training course. The relevant concepts and scope of abuse and neglect of older adults should be clearly defined, and the importance of older adult abuse in society and law should be emphasized. In-depth training and education should be provided to older adult care workers from both theoretical and real-life cases to facilitate timely detection and reporting of potential older adult abuse incidents and to reduce the occurrence of neglect.

The enthusiasm of older adult care workers toward participating in regular professional training should be improved, additional time should be provided, and older adult care workers should improve their energy for studies. The training courses should be scientifically and reasonably planned and fully combined with the actual training needs of the older adult care workers. More flexible methods, such as training methods for flipped classrooms or simulation model drills (35), can be adopted during the training while ensuring the participation of older adult care staff.

The low-income level is the main cause of neglect. The government can formulate relevant subsidy policies, fully implement the salary payment and subsidies for older adult care workers in long-term care facilities, and actively advocate for these institutions to pay their social insurance. Long-term care facilities should actively implement incentive policies to provide appropriate rewards for the spiritual, material, or economic aspects of care provision to maintain the enthusiasm of care workers and reduce the occurrence of neglect.

This study found that a large gap in the number of care workers and high labor intensity still exists, resulting in the increasing burden and risk of neglect. The government should actively lead the development of undertakings for older adult care workers, relieve the work pressure of older adult care workers by recruiting part-time nurses and experienced social workers, and support the training of these workers at an early stage. Long-term care facilities should reasonably schedule the amount of care and attempt to balance the supply-demand ratio. Colleges and universities should support the training of nurses interested in older adult care, promote employment agreements between colleges and long-term care institutions, and address the problem of proportion imbalance during the training of nurses.

This study did not conclude on a difference between personality traits and neglect. Future research can further explore the detailed relationship between personality characteristics and neglect through other approaches, such as the Traditional Chinese Medicine Constitution. This will help managers schedule workers for the most appropriate positions according to their different personalities and specific work requirements, which will ensure that they can make the best use of their talents (36).

Limitations and future directions

This study innovatively divides older adult neglect into different categories based on LPA for the first time and explores the influencing factors of neglect, providing an empirical study on the problem of neglect in the older adult care service system. This study has some limitations. First, this study only analyzed the differences in demographic data and personality characteristics of different categories of care workers, which may have other factors. Our study used a post-stratified convenience sampling method, which may have led to potential selection bias. In addition, this study was conducted in only Shandong Province, and the scope of sample collection was limited, which can limit the generalizability of the findings. Geographic and cultural differences may lead to a lack of representativeness in the results. Therefore, caution is needed when applying these findings to other regions or populations. In the future, other variables can be added to investigate large sample studies in different regions. Second, we used a cross-sectional design with no longitudinal follow-up of neglect. Our data only presents a snapshot of the current situation and does not permit causal inferences. Longitudinal studies should be conducted in the future to analyze influencing factors more accurately.

The sensitive nature of older adult neglect is also worth mentioning. Although before the beginning of the survey the researchers informed the older adult care workers of the research purpose and assured them of confidentiality, some workers may still be worried that the survey content will affect their work. This may result in untruthful answers due to concerns or fear, which can cause different degrees of information bias and subsequently influence the accuracy of the conclusion. Future studies should access information through multiple approaches, such as increasing objective assessments of older adult care or obtaining information from managers and older adults to ensure the reliability of the data.

This study found heterogeneity in the neglect of older adult care workers and divided the workers into three potential categories based on the LPA method. The study explored neglect of older people, complemented the existing literature, and provided directions for future research. Male older adult care workers and workers with low monthly income had a higher risk of neglect. Older adult care workers with employment qualifications, who attended training regularly, and who provided care to <4 older adults simultaneously had less risk of neglect. The managers of long-term care facilities should understand the individual characteristics of employed older adult care workers and identify and focus on the high-risk group of older adult care workers. In the future, different categories of influencing factors can be considered as the focus of intervention measures to reduce the occurrence of problems due to neglect, provide scientific guidance, and help long-term care facilities to develop policies regarding older adult care.

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 Shandong University's Institutional Review Board, Shandong University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

CY: Data curation, Writing – original draft, Conceptualization. CW: Writing – original draft. XD: Writing – review & editing. LS: Writing – original draft. WG: Writing – review & editing. DL: Supervision, Writing – review & editing.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1320896/full#supplementary-material

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Active aging and health among older adults in China: a perspective based on downward intergenerational economic support

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Introduction: In China, the rapid progression of population aging presents significant challenges to society and the economy, drawing widespread attention to the health conditions of older adults. While aging is often seen as a societal burden, the phenomenon of intergenerational economic support reveals the potential for older adults to continue playing an active role within their families. This study delves into how older parents' financial support to their children can reciprocally influence their own health, exploring the potential non-linear relationships involved.

Methods: This research, utilizing data from the 2018 China Health and Retirement Longitudinal Study, employs instrumental variable techniques and cross-sectional threshold models to examine how financial support provided by older adults to their children affects their health. It particularly highlights the varied impacts of economic support on older adults' health at different levels of support.

Results: The findings indicate that moderate intergenerational economic support significantly enhances the health of older adults, while either minimal or excessive financial support does not demonstrate the same positive effect. Additionally, subjective life expectancy plays a mediating role between intergenerational economic support and the health of older adults, further emphasizing the beneficial impact of economic support.

Discussion: The study underscores the importance of moderate intergenerational economic support in improving the health of older adults amidst aging challenges. Future policies and practices should consider how to encourage and optimize such support to address the challenges of an aging society, enhance the welfare of older adults, and promote healthy aging.

KEYWORDS

downward intergenerational economic support, health of older adults, mediating effects, instrumental variable models, cross-sectional threshold models

1 Introduction

The 21st century is widely recognized as the age of aging, a phenomenon driven by significant declines in fertility rates and extensions in life expectancy. This demographic shift has triggered concern for the health and well-being of older populations globally, especially in countries experiencing rapid aging. The World Health Organization's report on "Aging and Health" notes that by 2020, the global population aged 60 years and older surpassed the number of children under 5 years. By 2030, one-sixth of the world's population will be over 60, and by 2050, this figure is expected to rise to 2.1 billion. Notably, aging is no longer a characteristic unique to developed nations like Japan; by 2025, 80% of the older population will reside in low and middle-income countries (1). Specifically, China, the world's largest developing country, faces significant aging challenges. As of the end of 2022, the population aged 60 years and older in China was 280.04 million, accounting for 19.8% of the total population; those 65 and older accounted for 14.9%. The proportion of the population aged 60 and over in China increased by 0.9%, and those 65 and over by 0.7% compared to 2021, highlighting an intensifying trend of population aging (2). Concurrently, the health status of China's older adults is less than optimal, with over 190 million people aged 60 and older suffering from chronic diseases such as obesity, hypertension, and diabetes in 2022 (3, 4). As China's older population grows, improving their health status is crucial for advancing healthy aging and effectively responding to the national strategy against aging.

The World Health Organization defines healthy aging as maintaining and enhancing an individual's functional ability during old age, enabling them to stay healthy, participate in social life, and maintain independence and autonomy. This definition underscores the active role of older adults in society and families, noting that their health is not merely a matter of physical wellness but also their capacity to interact socially and achieve personal value. Simultaneously, the Chinese government has increasingly emphasized the promotion of a positive view on aging and the concept of healthy aging, implementing a series of policies and measures such as the "Opinions of the CPC Central Committee and the State Council on Strengthening Aging Work in the New Era" and the "National Plan for the Development of Aging Affairs and Elderly Care Service System during the 14th Five-Year Plan." These policies aim to tap into the potential of an aging society, invigorate its dynamics, and promote the healthy aging of older adults. Against this backdrop, the concept of intergenerational support gains more importance. Intergenerational support involves the reciprocal exchange of economic, life, and emotional assistance between generations within a family, sharing life experiences and resources (5). Such support is not limited to one-way assistance from children to older parents; older adults continue to support their children's daily lives in various ways, such as financing their children's home purchases or car buys, or caregiving for grandchildren. According to surveys, a significant portion of older adults engage in "financial recirculation" to their children. The survey data shows that 52.4% of older adults spend more on their children, primarily through financial support for home and vehicle purchases, accounting for 29.3 and 12.7%, respectively. Additionally, 43.5% of older adults also make purchases for their grandchildren, indirectly supporting their children financially (6).

Despite widespread attention to aging and its implications for individuals and society, current research lacks depth on how intergenerational support affects the health of older adults. Economic support, a common form of mutual aid in Chinese families, significantly influences the health and well-being of older adults. However, academic understanding of how older adults' downward economic support impacts their own health remains limited. This research gap is particularly critical in rapidly aging societies like China, where families play a central role in providing health and social support for older adults. This study aims to explore the relationship between intergenerational economic support provided by older adults and their health status, seeking to fill the gaps in existing literature and provide a scientific basis for policy-making.

2 Literature review and theoretical analysis

2.1 Literature review

Health is fundamental to ensuring that older adults enjoy their later years independently and autonomously. Enhancing the health levels of older adults is a critical task in building a healthy China and a proactive response to the challenges of an aging population. Since the late 1980s, the concept of health has expanded beyond mere physiological indices such as sickness and mortality rates to include a comprehensive concept encompassing physical, psychological, and social health. This expansion has complicated the construction of health indicators for older adults, leading to diverse opinions among scholars. For instance, Peter and Lorraine, among other scholars, use self-rated health to represent physical health status (7, 8), though this measure alone introduces a degree of subjective heterogeneity; Zhang divides the health of the older adults into three categories: physical health, cognitive function, and self-rated health (9); Okamoto assesses the intrinsic capabilities of older adults by evaluating challenges in basic and instrumental activities of daily living (ADL and IADL) and cognitive functions, considering also the certification status for public long-term care needs (10); Ye adopts the presence of chronic diseases as a measure of physiological health and evaluates the psychological health of the older adults through cognitive issues and depression symptoms (11); Lv and Zhang measure the physical health of older adults from both subjective and objective perspectives, using indicators such as receiving medical treatment and hospitalization (12); Yao and colleagues use the EQ-5D-3L scale's five dimensions as standards to assess individual health status, including mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, utilizing scores from the Visual Analog Scale (VAS) and utility values U to quantify quality of life (13).

Intergenerational support represents a bidirectional flow of resources between two generations within a family, encompassing economic support, caregiving, and emotional exchange (14). Extensive research has focused on the relationship between intergenerational support and health, predominantly examining support provided by children to older adults. Several studies have identified a positive correlation between upward intergenerational support and health. For example, Shu and colleagues, using structural equation modeling, found that upward intergenerational support from children can significantly improve the health of parents, especially their psychological well-being (15); Li and Guo, employing Heckman selection models and IV-Probit models, demonstrated that economic and emotional support from children can enhance parents' capabilities in Activities of Daily

Living and Instrumental Activities of Daily Living (16); Xu argues that living with children benefits the psychological health of older adults, and economic and emotional support from children has a significant positive impact on their psychological health (17). Qin's analysis using logistic regression models indicates that older adults who provide economic support have lower rates of poor self-rated health (18). Conversely, some studies suggest that excessive support from children can reduce older adults' sense of self-efficacy, leading to negative attitudes toward aging and diminishing psychological health (19).

While research on the health impacts of older adults' giving behaviors is less common, some scholars have examined intergenerational support from the perspective of older adults providing for their descendants. Thomas, using ordinary least squares regression, explored the impact of the type of support (given and received) on well-being, finding that providing support benefits older adults' welfare more than support received from spouses or siblings, including support provided to children (20); Peng and colleagues, through multivariate linear regression, discovered that older adults who financially support their children gain more self-esteem, thereby enhancing their well-being and improving their health conditions (21). However, Schwarz argues that the giving behaviors of older adults can also have adverse effects on their psychological health if elders continually assist younger generations, which may be perceived as a failure in parental education, thus placing psychological pressure on older adults (22).

In summary, while previous studies provide a robust foundation for exploring the relationship between intergenerational support and the health of older adults, there is still room for improvement and addition. Although the relationship between intergenerational support and the health or welfare of older adults has been extensively discussed, research on downward intergenerational support remains insufficient. The academic consensus on whether intergenerational support positively impacts older adults' health is not yet unified, with most empirical studies examining linear relationships between economic support and health, while few consider potential nonlinear relationships. Moreover, many studies examine health from various dimensions but typically analyze the relationship between intergenerational support and older adults' health from a singular health perspective, especially psychological health. Thus, this paper will analyze the relationship between downward intergenerational economic support and the comprehensive health status of older adults from the perspective of downward intergenerational economic support, utilizing instrumental variable methods to identify the impact of intergenerational economic support on older adults' health status. To explore the nonlinear relationship between intergenerational economic support and older adults' health, threshold regression models will be further employed to investigate the threshold effects of downward intergenerational economic support on older adults' health, aiming to explore pathways and challenges to enhancing the quality of life and living standards of older adults, thereby providing theoretical reference and practical guidance for relevant economic and social decisions.

2.2 Theoretical analysis

2.2.1 Intergenerational economic support and older adults' health

Within the framework of family economics, individuals often exhibit altruism and a preference for family coherence, incorporating the needs of other family members into their labor supply decisions (23). Influenced by the ethics of family-centric responsibilities, parents often provide for their children and family selflessly, resulting in a downward allocation of resources within the family (24). In China, most older adults rely on themselves as much as their health permits and provide financial support to their children to alleviate their living pressures. This willing provision of support, sometimes humorously referred to as being 'nibbled on' by one's own children, is seen by many older adults as a fulfilling part of parental duties. Witnessing their children's improved living conditions due to their support not only brings older adults a sense of achievement and satisfaction but also positively impacts their mental and physical health.

2.2.2 Intergenerational economic support, subjective life expectancy, and older adults' health

Subjective life expectancy reflects older adults' unique perception of their aging process, embedding these perceptions into their self-concept and identity (25). The arrangements and plans people make for their future lives are influenced by their expected lifespan. Providing economic support to children implies that older adults need to work and have their own sources of income. Activity theory suggests that maintaining social activity can slow the aging process (26), fostering a positive view of aging among older adults. The process of earning an income independently provides older adults with a sense of self-worth. Consequently, intergenerational economic support can positively affect older adults' views on aging and enhance their subjective life expectancy. A positive attitude toward aging can significantly reduce the occurrence of psychological issues such as depression, thus improving older adults' health levels.

3 Models and methods

3.1 Baseline regression model

Building on the analysis presented, this study constructs a baseline regression model to empirically test the impact of intergenerational economic support on the health status of older adults:

$$Health_i = \beta_0 + \beta_1 Gene_i + \beta_2 Controls_i + \varepsilon_i \quad (1)$$

In Equation (1), $Health_i$ represents the overall health status of older adults; $Gene_i$ denotes intergenerational economic support; $Controls_i$ includes a series of control variables, such as the gender, age, income, number of living children, number of grandchildren, and satisfaction with child relationships of the surveyed older adults; i indexes the sample; β_0 is the constant term; β_1 & β_2 represent the estimated coefficients; ε is the random error term.

3.2 Threshold regression model

Traditional linear regression methods do not address structural breaks. The impact of intergenerational economic support on older adults' health may vary with the level of financial support provided to their children, exhibiting distinct characteristics. Therefore, this study employs the threshold model proposed by Hansen (27) to further

examine how intergenerational economic support affects older adults' health across different support intervals. The model is expressed as follows:

$$Health_i = \delta_i + \alpha_1 Gene_i I\left(Gene_i \le \varphi\right) + \alpha_2 Gene_i I\left(Gene_i > \varphi\right) + \alpha_n Controls_i + \sigma_i \quad (2)$$

In Equation 2, $Health_i$, $Gene_i$, and $Controls_i$ have the same meanings as in Equation 1; I(·) represents the indicator function; δ_i is the constant term; $\alpha_1,\alpha_2,\alpha_n$ are coefficients of the influencing factors; σ_i is the random error term.

3.3 Mediation effect model

To more finely explore the mechanisms through which intergenerational economic support impacts older adults' health, based on the theoretical analysis, a stepwise regression method (28) is used to validate the mediation effect model, set up as follows:

$$Health_i = \beta_0 + \beta_1 Gene_i + \beta_2 Controls_i + \varepsilon_i \quad (3)$$

$$Life_i = \theta_0 + \theta_1 Gene_i + \theta_2 Controls_i + \partial_i \quad (4)$$

$$Health_i = \epsilon_0 + \epsilon_1 Gene_i + \epsilon_2 Life_i + \epsilon_3 Controls_i + \omega_i \quad (5)$$

Equation 3 tests the impact of intergenerational economic support on older adults' health; Equation 4 examines the influence of intergenerational economic support on subjective life expectancy; and Equation 5 tests the mediation effect of subjective life expectancy. Here, $Health_i$ represents older adults' health; $Gene_i$ is intergenerational economic support; $Life_i$ is the subjective life expectancy of older adults; $Controls_i$ represents the control variables; $\beta_0,\theta_0,\epsilon_0$ are constant terms; $\beta_1,\beta_2,\theta_1,\theta_2,\epsilon_1,\epsilon_2,\epsilon_3$ are coefficients of the influencing factors; $\varepsilon_i,\partial_i,\omega_i$ are random error terms.

4 Data source, variable selection, and descriptive statistic

4.1 Data source

This study utilizes data from the China Health and Retirement Longitudinal Study (CHARLS), which is a long-term project managed by the National Development Research Institute of Peking University. The CHARLS project aims to collect longitudinal data on the health, retirement, and economic status of the Chinese population aged 45 and above. The sampling design of CHARLS considers the representativeness of the national population, employing Probability Proportional to Size Sampling (PPSS) and Computer Assisted Personal Interviewing (CAPI) techniques to randomly select multi-stage samples (county/district-village/community-household), ensuring comprehensive coverage (29). The project team has implemented high-standard training and strict data quality control measures to ensure consistency and accuracy in data collection. The design and implementation framework of CHARLS, detailed in the cohort profile by Zhao et al. published in the International Journal of Epidemiology, validates the reliability and validity of the survey (30). The data source relied upon in this study demonstrates high credibility and validity, providing a solid foundation for our analytical results.

The 2018 questionnaire included sections on family information, health status, cognition and depression, healthcare and insurance, work and retirement, asset income, and property, among others. Based on these considerations, the data is deemed to align well with the objectives of this paper, namely, the relationship between intergenerational economic support and the health of older adults. Therefore, according to the definitions of older adults by global organizations and the Chinese government, specifically those aged 60 and above (31), this study selects samples of individuals aged 60 or older who have children. Due to the CHARLS questionnaire allowing respondents to opt for "refuse to answer" or "do not know," samples missing key variables such as economic support and health were excluded, ultimately retaining a total of 5,137 sample data points.

4.2 Variable definition and descriptive statistics

(1) Dependent Variable: Overall Health of Older Adults. This study measures the health of older adults using both subjective and objective indicators. This includes self-assessed health status ("How would you rate your health?"), physical health (including "suffering from pain" and "presence of chronic diseases"), and mental health indicators derived from an epidemiological survey on depression, such as "bothered by trivial things," "difficulty concentrating," "feeling down," "everything feels like an effort," "feeling fearful," "sleeping poorly," "feeling lonely," and "feeling unable to carry on with life." A measurement model is used to compute the overall health status of the respondents.

(2) Explanatory Variable: Intergenerational Economic Support. This is determined by asking older adults about the amount of economic support (both monetary and in-kind) they have provided to their children over the past year.

(3) Instrumental Variables. The study explores the causal relationship between intergenerational economic support provided by older adults to their children and their health status. Given the potential strong endogeneity between intergenerational economic support and health—where healthier older adults may be able to work longer and provide more support, and conversely, where various uncontrolled factors could affect health—this study uses instrumental variables for estimation. Education level and marital status are chosen as instrumental variables. Education, as a socio-economic resource, influences a person's socio-economic status, thereby affecting intergenerational economic support. Additionally, spousal agreement can significantly influence the decision to provide financial support to children. However, education and marital status do not directly impact older adults' health, thus theoretically validating the choice of these instrumental variables.

(4) Mediating Variable: Subjective Life Expectancy. Subjective Life Expectancy. Based on the theoretical analysis discussed previously, this paper selects subjective life expectancy as the mediating variable. The questionnaire assesses whether respondents believe they can live to specific ages, which correspond to their current age group: individuals aged 60–65

are asked if they expect to live to 75, those aged 65–69 to 80, those aged 70–74 to 85, those aged 75–79 to 90, those aged 80–84 to 95, those aged 85–89 to 100, those aged 90–94 to 105, those aged 95–99 to 110, and those over 100 to 115.

(5) Control Variables. Reflecting individual characteristics and family dynamics, the study includes sex, age, income, number of living children, number of grandchildren, co-residence with children, and satisfaction with child relationships as control variables. Table 1 presents the definitions of these variables along with descriptive statistics.

According to the descriptive statistics shown in Table 1, the health status of older adults in the sample is uniformly distributed, indicating that there is a similar proportion of respondents with good health and poor health. In terms of downward intergenerational support, the data shows that, on average, older adults provide their children with financial assistance amounting to 3,248 yuan, reflecting the traditional Chinese family norm of intergenerational mutual aid. Notably, the proportion of older adults living with their children is relatively low, which may be attributed to changes in family structures in China and the mobility of younger generations. Marital status data further indicates that many older adults are either living alone or cohabiting with their spouses. The expected subjective lifespan is also relatively high, showcasing the prevailing retirement views among Chinese older adults. Additionally, the average educational level among the older population is relatively low, which could influence their capacity and methods for providing economic support.

5 Regression analysis of intergenerational economic support on older adults' health

5.1 Regression results

The regression results, as shown in Table 2, indicate the impact of intergenerational economic support on the health status of older adults. Model 1, which includes all control variables, demonstrates that the majority of these variables significantly affect the health of older adults. Specifically, gender, age, the number of living children, and the number of grandchildren have a negative impact, whereas income, co-residence with children, and satisfaction with child relationships positively influence older adults' health. Model 2 incorporates intergenerational economic support into the analysis and shows that the coefficient for intergenerational economic support is positive and significant at the 5% level. This suggests that providing financial support to children significantly improves the health of older adults, possibly because such support enhances their sense of being needed and valued, thereby positively affecting their physical and mental health.

To address potential endogeneity in the analysis, Model 3 employs the Two-Stage Least Squares (2SLS) method with robust standard errors. The validity of the instrumental variables is confirmed through a series of tests: the underidentification test (p-value <0.01), weak instrument test (F-statistic 111.104, exceeding the 10% critical value of 19.93), and overidentification test (p-value 0.840, indicating no overidentification issues), affirming the reliability of the instruments used. The regression coefficient for intergenerational economic support in Model 3 is 0.021, which is highly robust at the 1% significance level. This finding underscores the critical role that moderate economic support plays in enhancing the health of older adults and suggests that there may be an optimal level of financial assistance that maximizes health benefits. Comparing the OLS results from Model 2 with those from Model 3 indicates that the OLS may underestimate the positive effects of intergenerational economic support on older adults' health, although the overall conclusions are consistent. For instance, with every 1% increase in the amount of economic support provided, there is a corresponding 0.021% improvement in the health status of older adults.

5.2 Threshold regression results

To explore whether the impact of intergenerational economic support on the health status of older adults varies across different

TABLE 1 Variable definitions and descriptive stats.

Variable type	Variable	Definition	Mean	Std. Dev.
Dependent	Overall health	Older adults health, mean = 0	−0.009	0.581
Independent	Intergenerational economic support	Total value (in thousands) given to children (monetary and goods)	3.248	10.061
Control	Gender	Female = 1; Male = 0	0.472	0.499
	Age	Respondent's age (years)	68.285	6.192
	Income	Total income (wages and transfers) logged	7.327	3.051
	Living children	No. of living children	3.147	1.512
	Grandchildren	No. of grandchildren	4.593	3.148
	Co-residence with children	Co-residing with children = 1; No = 0	0.148	0.355
	Satisfaction with child relations	Satisfied = 1; Not satisfied = 0	0.959	0.263
Instrumental	Highest education	Illiterate = 1; Elementary = 2; Junior high = 3; High school = 4; College or above = 5	1.974	1.097
	Marital status	Co-residing with partner = 1; No = 0	0.841	0.366
Mediating	Subjective life expectancy	Possible = 1; Not possible = 0	0.623	0.485

TABLE 2 Regression analysis of intergenerational economic support on the health of the older adults.

Variables	Model 1	Model 2	Model 3
Intergenerational economic support		0.002** (0.001)	0.021*** (0.004)
Gender	−0.170*** (0.016)	−0.170*** (0.016)	−0.171*** (0.017)
Age	−0.003* (0.001)	−0.003** (0.001)	−0.003* (0.002)
Income	0.025*** (0.003)	0.024*** (0.003)	0.014*** (0.003)
Number of surviving children	−0.022*** (0.008)	−0.022*** (0.008)	−0.014 (0.009)
Number of grandchildren	−0.011*** (0.004)	−0.010*** (0.004)	−0.007 (0.004)
Co-residence with children	0.030 (0.022)	0.032 (0.022)	0.053** (0.024)
Satisfaction with children	0.223*** (0.030)	0.225*** (0.030)	0.236*** (0.031)
Constant	−0.031 (0.096)	−0.034 (0.096)	−0.066 (0.102)
R^2	0.074	0.075	
Instrument unavailability test			117.552***
Weak instrument test			111.104
Over-identification (*p*-value)			0.840
Estimation method	OLS	OLS	2SLS

*, **, ***indicate significance at the 10, 5, 1% levels.

TABLE 3 Threshold effect test.

Model	*F*-value	*p*-value	Bootstrap (BS)	Critical values		
				1%	5%	10%
Single	19.865***	0.000	300	6.386	4.397	3.317
Double	3.924**	0.033	300	6.089	2.283	0.255
Triple	2.994	0.103	300	9.211	4.432	3.190

*, **, ***indicate significance at the 10, 5, 1% levels.

threshold intervals, we conducted a threshold regression analysis based on the initial study. The results, presented in Table 3, reveal significant threshold effects. The test for a single threshold yielded a *p*-value of 0.000, significant at the 1% level; the double threshold showed a *p*-value of 0.033, significant at the 5% level; and the triple threshold had a *p*-value of 0.103, not significant. Consequently, the double threshold model was selected for empirical analysis.

Threshold estimates and confidence intervals obtained in the double threshold model, as shown in Table 4, indicate a single threshold value of 0.060 within a 95% confidence interval of [0.008, 56.500], and a double threshold value of 20.000 within a 95% confidence interval of [15.000, 21.000]. Based on these thresholds, the older adults in the sample ($N = 5{,}137$) were categorized into three groups: minimal intergenerational economic support (≤ 0.060), moderate support ($0.060 < \text{support} \leq 20.000$), and substantial support (>20.000). Further

TABLE 4 Estimated threshold values and confidence intervals.

Model	Estimated value	95% Confidence interval
Single threshold	0.060	[0.008,56.500]
Double threshold	20.000	[15.000,21.000]

exploration of the effects within these threshold intervals on older adults' health is discussed below based on Table 5.

The results illustrate a significant nonlinear relationship, termed the "double threshold effect," in the impact of intergenerational economic support on older adults' health. When economic support is below the threshold of 0.060, the coefficient is −4.105, significant at the 5% level, suggesting that minimal economic support (less than 60 units of currency) adversely affects older adults' health. This could be due to minimal interaction and emotional exchange between these older adults and their children, as well as poorer economic conditions and less investment in health, compounded by the decline in physical functions with age.

For support levels between 0.060 and 20.000, the coefficient is 0.013, significant at the 1% level, indicating that moderate levels of economic support positively impact older adults' health. This support likely enhances their sense of self-worth and strengthens emotional bonds within the family, which are crucial for both mental and physical health.

Conversely, when economic support exceeds the threshold of 20.000, the effect on health is not significant, suggesting that excessive financial support does not improve the health of older adults. This scenario likely reflects the limited earning capacity of older adults, where excessive support could strain their finances and health, as the high demands of providing substantial support exceed their physical capabilities. Thus, while economic support can be beneficial, there is an optimal range beyond which no additional health benefits are observed.

5.3 Robustness checks

To verify the robustness of the main regression results, this section introduces tests that exclude certain age groups and employ alternative dependent variables for robustness checks.

5.3.1 Excluding younger age samples

As individuals age, physical capabilities generally decline, meaning that older adults in the lower age range (60–69 years) might still retain better physical and labor capabilities compared to their older counterparts. To test the robustness of our findings, we reanalyzed the data excluding this younger cohort. The results, presented in Table 6, confirm that intergenerational economic support significantly and positively affects the health of older adults at a 5% significance level, with the direction and strength of control variables consistent with previous findings.

5.3.2 Replacing the dependent variable

To further validate the reliability of our results, we employed the Physical Function Disability Scale as an alternative dependent variable. This scale provides an objective assessment of sensory and motor functions, crucial for gaging the physical quality of older adults. The regression results, also detailed in Table 6, remain consistent with the main findings, underscoring the robustness of the empirical outcomes.

TABLE 5 Cross-sectional threshold model regression results.

Variable	Low IGS (IGS ≤ 0.060)	Moderate IGS (0.060 < IGS ≤ 20.000)	High IGS (IGS > 20.000)
Inter-generational economic support (IGS)	−4.105** (1.688)	0.013*** (0.003)	0.000 (0.002)
Constant	−0.025 (0.132)	−0.078 (0.148)	0.029 (0.438)
Control variables	Control		
R^2	0.076	0.076	0.109
N	2,862	2045	230

*, **, ***indicate significance at the 10, 5, 1% levels.

5.4 Mediation effect analysis

According to Table 7, the first column shows that the total effect coefficient of intergenerational economic support on older adults' overall health is positive and significant at the 5% level. The second column indicates that the regression coefficient of intergenerational economic support on older adults' subjective life expectancy is positive. Concurrently, the third column reveals that the estimated coefficient of economic intergenerational support on older adults' health status is significantly positive, suggesting an indirect effect. Additionally, in the third column, the coefficient of subjective life expectancy on older adults' overall health status is significantly positive at the 1% level, indicating that economic intergenerational support also has a significant direct effect on older adults' health. All regression coefficients being positive indicate that subjective life expectancy partly mediates the relationship between economic intergenerational support and older adults' health status. This may be because as older adults provide economic support to their children, they find their place in their later years and can still realize their worth through their labor, fostering a positive and healthy aging perspective. This uplifting philosophy of life also enhances older adults' subjective life expectancy. Moreover, an increase in subjective life expectancy suggests satisfaction with their health status and contentment with life in older age, which positive emotions can beneficially influence older adults' health status.

TABLE 6 Robustness results.

Variable	Excluding low-age samples (1)	Substituting dependent variable (2)
Intergenerational economic support	0.015** (0.006)	0.283*** (0.056)
Control variables	Control	
R^2	0.043	.
N	2,128	3,690

*, **, ***indicate significance at the 10, 5, 1% levels.

TABLE 7 Mediation effect results of subjective life expectancy.

Variable	General health	Subjective life expectancy	General health
Intergenerational economic support	0.002** (0.001)	0.002** (0.001)	0.001* (0.001)
Subjective life expectancy			0.395*** (0.016)
Control variables	Control		
R^2	0.075	0.093	0.173
N	5,137	5,137	5,137

Standard errors in parentheses. *$p < 0.05$, **$p < 0.01$, **$p < 0.001$.

6 Conclusion and implications

In recent years, with the transformation of social structures and family patterns in China, intergenerational economic support between older adults and their children has emerged as a significant factor influencing elder health. This study challenges the traditional view that intergenerational support flows unidirectionally from children to parents. Our analysis reveals that by providing economic support to their children, older adults actively enhance their own health and quality of life, demonstrating that intergenerational support within families is a bidirectional and dynamic interaction. In China, even in later life, parents continue to support their children through household chores, grandparenting, and financial contributions, thereby maintaining their productivity (32). Older adults gain a sense of self-worth through supporting their children and respect through receiving support from them (33). In the context of traditional Chinese family culture, children are tasked with the responsibility of maintaining the health and care of the older adults, while parents also play a longstanding role in caring for their children. Thus, the impact of downward intergenerational support on health may often be overlooked. This paper, utilizing data from the 2018 China Health and Retirement Longitudinal Study and employing instrumental variable and threshold regression models, empirically analyzes the relationship between intergenerational economic support and older adults' health, while also examining the nonlinear impact of intergenerational economic support across different threshold ranges. By incorporating a mediation effect model, the study further explores how subjective life expectancy influences the relationship between intergenerational economic support and older adult health.

Key findings include: First, there is a positive link between the economic support older adults provide to their children and their own health status. This link remains stable even after excluding younger older adult samples, indicating its broad applicability. This aligns with previous research suggesting a positive correlation between intergenerational support and older adults' subjective well-being (34, 35). Li found that providing intergenerational support has a significant positive effect on perceived health.

Additionally, scholars have found from the perspective of older adults' life satisfaction that financial transfers to children correlate positively with the life satisfaction of older adults in China (36). Previous studies have mostly examined aspects like happiness, life satisfaction, and mental health among the older adults. This paper's comprehensive indicators of perceived health, physiological health, and mental health extend and support reported results between downward intergenerational economic support and elder health, emphasizing its significance. Second, the study uncovers a dual-threshold effect of intergenerational economic support. Notably, moderate financial support from older adult parents to their children significantly enhances their health level, whereas excessive economic support has no significant effect (37). It is clear that providing financial support correlates positively with older adult health. However, economic pressure is a strong predictor of older adult health. Excessive financial support may indicate overwhelming economic pressure and overwork for the older adults, thus not significantly benefiting their health. This finding suggests that a balance must be found in the provision of intergenerational support, which is crucial for understanding how older adults can support their children without compromising their own quality of life. Third, subjective life expectancy plays a partial mediating role in the relationship between intergenerational economic support and older adults health, with significant mediation effects. This discovery emphasizes how older adults' expectations for the future influence their daily behaviors and health status. Social support theory posits that intergenerational support benefits older adults' capabilities and psychological resilience mechanisms (38). In China, older parents are reluctant to receive excessive economic support from their children, fearing it may burden them (39). Instead, they continue to provide significant support for their children and families, thereby gaining self-esteem, affirming their self-worth, and positively influencing their subjective life expectancy.

This paper's findings offer several insights: First, providing a certain amount of financial support helps promote the physical and mental health of older adults, but excessive financial burdens can bring stress and adverse effects. Thus, it is crucial to find a sustainable support model to ensure that older adults' health and welfare are not compromised by undue economic burdens. Employment can enable older adults to earn an income, realize their self-worth, and achieve mental fulfillment, which is beneficial for their health (40, 41). National and social organizations should provide opportunities for older adults to re-engage in the workforce, helping them realize their self-worth through work and ensuring they receive appropriate economic support at different life stages. Policies should also be developed to protect the rights of older adults in the workforce, providing them with employment and entrepreneurial subsidies. Second, the social support system for the older adults should be improved to reduce their economic burdens. Strengthening social security for the older adults, such as health insurance and pensions, can help reduce the risk of poverty due to illness. Additionally, the government should implement targeted economic assistance programs for the older adults, such as housing subsidies and living allowances, to ensure their quality of life post-retirement. Lastly, a scientific approach to intergenerational support should be advocated. Through education and advocacy, traditional societal views of the older adults should be changed, recognizing that older adults can still contribute meaningfully to society and their families in appropriate ways. At the same time, children's financial support to the older adults should be moderate, avoiding demands that exceed the older adults' capacity, thus protecting their self-esteem and self-efficacy, and promoting their health.

While this study robustly argues for the relationship between downward intergenerational economic support and older adult health, it still has some limitations. First, the use of cross-sectional threshold effects may overlook the average effects caused by temporal development, only estimating short-term effects. Future research could utilize panel data or longitudinal study designs to track individual changes over time for a more accurate understanding of these dynamics. Second, while this study uses samples from various regions in China, it cannot fully represent all areas, especially those in remote regions. Future studies could consider urban–rural differences, economic levels, and social class disparities. Lastly, this study explored the role of subjective life expectancy as a mediating variable, but there may be multiple mediating pathways between intergenerational support and older adult health. Future research could consider other potential mediators such as psychological stress, quality of life, and social participation.

Data availability statement

To ensure transparency and reproducibility of this study, the primary data relied upon was sourced from the China Health and Retirement Longitudinal Study (CHARLS). Researchers interested in further investigation can access this data by visiting the official CHARLS website and adhering to the relevant data usage protocols. Access to the data requires registration and application through their website. For more information about CHARLS data, please refer to: https://charls.pku.edu.cn/.

Ethics statement

The studies involving humans were approved by the Institutional Review Board (IRB) at Peking University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

LY: Conceptualization, Methodology, Writing – review & editing. ZX: Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

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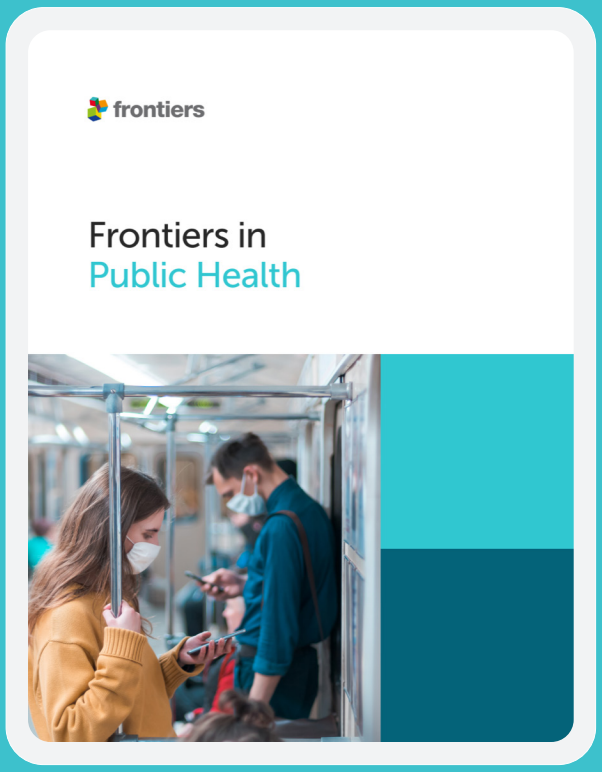

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